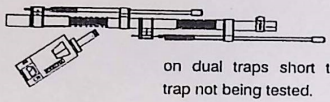
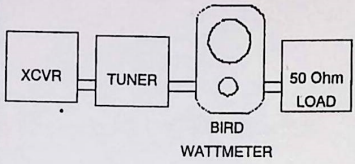
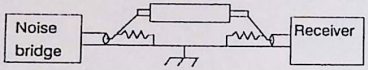
TROUBLESHOOTING ANTENNAS AND FEEDLINES

Inductive couple to an open style trap that has the capacitor to the side of the coil

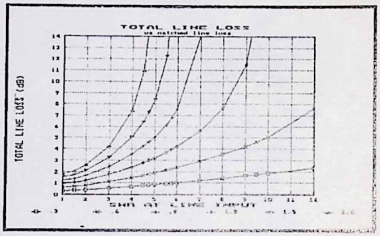


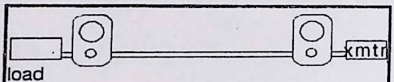
on dual traps short the trap not being tested.





The resistors are 18 Ohms. I built this test set up into a length of coax cable. Connectors are on each end of the cable to attach to receiver and noise bridge. Clip leads are used to attach to each end of the trap.

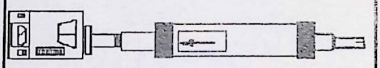




P1 coax under test P2

Put the wattmeter at the output of the transmitter and measure the power. Then move the wattmeter to the other end of the feedline and again measure the power. Matched line loss is determined as shown below in the LOSS formula.

Capacitive couple to a trap with a covered coil



To adjust frequency remove the plastic caps, remove a self tapping screw, slide the outer tube along the inner tube until the trap is set to frequency. Drill a small hole so that the self tapping screw can be installed.

Frequently Asked Questions:

- I am using coax to feed my antenna. Do I need to use a balun?
- Should I use a certain length of feedline to my antenna?
- And many others . . .

by Ralph Tyrrell, W1TF

MFJ Publishing

TROUBLESHOOTING ANTENNAS AND FEEDLINES

Ralph Tyrrell, W1TF

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My thanks to Dave Olean, K1WHS and Bob Morton, VE3BFM. Each has spent hundreds of hours with me discussing antennas and feed lines during the last six years. I have enjoyed their company and much of what I know about antennas and feed lines I learned from them.

To my wife Kathryn, N1INC, I give loving thanks for encouraging me during the many months that it took to prepare the material for this book.

Special thanks to Bob Morton, VE3BFM, for editing my material prior to publication.

FORWARD

An antenna system that works well on transmit will also work well on receive; if your antenna system is lossy on transmit due, to excessive coax cable loss or impedance mismatch, you will also have this loss on receive. As I was once told, "If you can't hear them you can't work them".

Troubleshooting Antennas is the type of book you should read completely if you have never installed an antenna before. It covers a wide variety of items that most people, experienced with antennas, do instinctively, but likely have gained this experience through making mistakes themselves.

Using this book as a reference may save you hours of grief or finally answer the question of why your antenna system never really worked the way you expected it to perform.

I use "antenna system" instead of just antenna because you could put up the best antenna on the market, and then feed it improperly with lossy coax to yield poor signal strengths.

The definition of words at the end of this book explains many terms relating to antennas. The dictionary section properly completes the book and helps make reading more understandable.

Bob Morton, VE3BFM / NI1W

Product Manager

Sinclabs Inc. (Subsidiary of Sinclair Radio Laboratories)

September, 1991

INTRODUCTION

An antenna is a device that couples your radio equipment to the propagation median for the purpose of transmission or collects a radio signal from a passing wave and turns it into an electrical signal for the purpose of reception. The strength of the radiated energy from an antenna depends on the amount of current flowing in the radiating element or elements as well as the shape and size of the element or elements and the local environment. During transmission, current from your transmitter flows thru the transmission line and into the antenna. The current in the antenna will produce electro-magnetic waves. These waves are radiated away from the antenna and into space. We hope that the propagation median will support these waves until they arrive at the desired destination. There is more potential loss of signal and station performance within the antenna-feedline system than any other part of the amateur radio station.

Your choice of antenna depends on many factors; the frequency(s) you will be using, the importance of antenna performance to you, the amount of space available for this project, your understanding of antennas, the money available, the materials that are available, and restrictive covenants that may apply.

The "I made it myself pride" has long been an important part of ham radio but is being lost due to technical advances in electronics and lack of availability of components to the individual. The antenna and its installation continues to be an area in which hams can "home brew" and take pride.

This book is intended for the person that is not comfortable with antennas or feed lines. Some of the basic antennas that are available from manufacturers or are commonly built by amateurs will be explained. Suggestions for antennas that might be used where restrictive covenants prevail are offered. A review and explanation of use of the pieces of test equipment normally used to test and troubleshoot antennas and feed lines will be presented.

It is hoped that this book will help you with a better understanding of antennas, plus get you on the air to enjoy the equipment you have and fellowship with other hams.

Ralph Tyrrell, W1TF

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ANTENNA FUNDAMENTALS

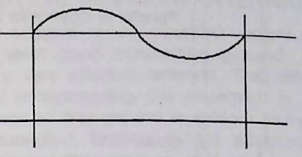
The efficiency of an antenna will depend on the materials used in its construction, its size, shape and proximity to other objects which can influence the manor in which current will flow in the antenna elements.

The efficiency of the transmission line that delivers the power from your transmitter to the antenna depends on the materials used. This includes the insulation value of the dielectric, the size and configuration of the conductors, as well as the matching of the transmitter to the transmission line impedance, and the matching of the transmission line impedance to the antenna impedance.

On reception, the transmission line efficiency is just as important, and the same factors are involved as in transmission. One other factor involved in reception is the necessity to keep locally generated noise from arriving at the receiver along with the desired signal. Noise sources can be electric tools, florescent lights, ignition circuits in automobiles, ignition circuits for furnaces and water heaters. Almost any use of electricity may have the potential of creating noise that will interfere with the signal you desire to listen to. Keep the antenna away from noise sources. A properly used transmission line may pass through noisy areas without picking up noise and passing it to the receiver.

TRANSMISSIONS LINES

When a generator with sinusoidal output (a transmitter) is attached to a transmission line that is terminated in a matching resistive load, the RF energy from the generator is assumed to be propagated down the transmission line toward the load end with the current and voltage in phase. A wavelength is defined as the distance the wave must travel to complete a phase change of 360 degrees.



One wavelength is the distance a wave must travel in one cycle of time. It is measured from the point on the waveform where it crosses the axis going positive until the next point of crossing where it is going positive again. In free space a wavelength in feet is equal to 984.25 / frequency in MHz.

The characteristic impedance of a line is determined by the physical dimensions of the line and is given by:

$Z = 276 \log b/a$ for air dielectric parallel lines

where

- Z is the Characteristic impedance
- b is the conductors center to center distance
- a is the radius of conductors

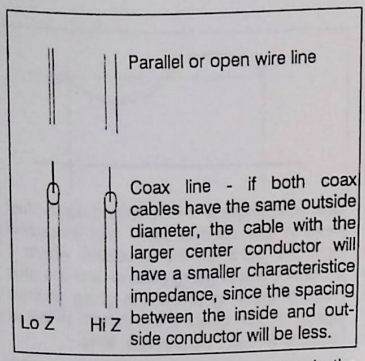
OR

$$Z = \frac{138 \log b/a}{\sqrt{Er}}$$ for coaxial lines

where

- Z is the Characteristic impedance
- a is the inside diameter of the outer conductor
- b is the outside diameter of the inside conductor
- Er is the dielectric constant of material between conductors

It will be adequate for now if you notice that larger spacings will give a larger characteristic impedance. If the load (antenna) at the end of the line is equal to the characteristic impedance of the line then all energy traveling down the line is absorbed by the load. This is the most efficient and desirable condition.


Parallel or open wire line
Coax line - if both coax cables have the same outside diameter, the cable with the larger center conductor will have a smaller characteristice impedance, since the spacing between the inside and outside conductor will be less.
Lo Z
Hi Z

When the line is perfectly terminated, the voltage across the line will be the same at all points along the line. This condition is called a flat line. If the load does not equal the characteristic impedance of the line, then some energy will not be absorbed by the load and that energy will be reflected back down the transmission line toward the transmitter. When this condition occurs, the voltage and current are not in phase along the transmission line, and the VSWR is no longer 1:1 (one to one). The amount of energy reflected back toward the transmitter is a ratio of the impedance of the line to the impedance of the load. In modern transmitters this reflected power is monitored, and if it exceeds a certain percentage of the forward power, the output power of the amplifier will be limited so that the transistors in the amplifier will be protected. Therefore, matching of transmission line to antenna is important in order to get the maximum output power from the transmitter.

If a line is infinitely long, energy would continue to move down it, slowly dissipating (because of losses). It would not matter if the line were terminated or not, and the energy from the source would never find a mismatched end, which would cause some energy to be reflected and return to the source.

When a finite length of transmission line is used and is terminated in a resistive load equal to the characteristic impedance of the line, all the energy at the load end will be absorbed by the load. There will be no reflected power.

When a finite length of line is used and is terminated in a load that is not equal to the characteristic impedance of the line, not all of the energy will be absorbed by the load. The energy not absorbed will be changed in phase and reflected back toward the source (transmitter). The ratio of the magnitude of the reflected wave (current or voltage), to the magnitude of the incident wave (current or voltage), is called the reflection coefficient and determines the standing wave ratio. In this book voltage standing wave ratio (VSWR) will usually be used.

Most amateur radio equipment and commercial antennas have 50 Ohm input and output impedances (TV receive antennas are usually 75 Ohms). Therefore, 50 Ohm lines such as RG8 or RG58 will be used. An antenna tuner may be used where the impedance presented to the radio equipment is not 50 Ohms. An antenna tuner will cancel reactance and change resistance to 50 Ohms so that the equipment will work efficiently.

THE DIPOLE ANTENNA (HERTZ ANTENNA)

Probably the simplest of antennas is the dipole. This antenna will be resonant when the electrical length is a half wavelength. The length of the overall wire should be:

468/FREQUENCY MHz = LENGTH (FT)

A dipole for 7.125 MHz would be

468/7.125 = 65.68 FEET

Dipole

Dipole with ends bent down

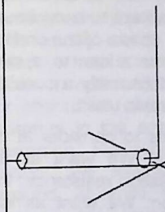
Dipole mounted in the shape of an inverted

With bent or drooping ends make the wire a bit longer to optain resonance at the desired operating frequency..

Cut this wire in half, install insulators at each end and between the two half's at the center. The two wires of the transmission line should be separated and one wire should be connected to the antenna wires on each side of the center insulator of the dipole. While the above formula will give you lengths to try, don't expect the result will always be exact. A 40 meter dipole mounted at 70 feet would have to be about 2 feet shorter if it is mounted at 30 feet (ground effect). If you do not have 66 feet between supports to mount the above antenna, then bend the ends as shown. If 10 feet on each end is bent down, then expect to lengthen each end by about 1 foot to maintain resonance at the same frequency. Another method of mounting a dipole is to get the center of the dipole as high as possible. The ends of the antenna may be attached to lower points. The shape will be as an inverted letter "V". The length of the wires will have to be about 1 foot longer on each side to maintain the same resonant frequency.

THE QUARTER WAVELENGTH VERTICAL (MARCONI ANTENNA)

Half of a dipole, when mounted vertical and fed against good conducting ground, can make a very effective antenna. The difficult part of understanding this statement is that good conducting ground is seldom found in your backyard. Radials (wires) attached to the base of the antenna and laid on the ground, or buried just under the ground, are very important to the efficiency of the quarter wavelength vertical antenna. Almost all AM broadcast antennas are of this type. The base impedance of this antenna is about 36 Ohms. This will cause only a small mismatch when connected to a 50 Ohm coax transmission line. The Cushcraft AP8 antenna solves that mismatch problem with a transformer at the feedpoint to insure a low VSWR. Many antenna manufacturers turn the quarter wavelength vertical antenna into a multi-band antenna by adding traps for the different bands along the length of vertical tubing.



The quarter wavelength antenna. This Antenna must have a low resistance ground to be efficient. Commom practice is to use 3 or 4 radials laying on the ground or buried about 1 inch. Improved results will be obtained with 15 to 20 radials. A ground long rod is important for lightning protection but does not improve antenna preformance.

Remember that the quarter wavelength antenna is only half of an antenna and will not work all by itself. It does require a good ground or radials to turn it into an efficient radiator. Only when you have a half wavelength of wire or tubing will you have a resonant antenna system. The conductive ground or radials acts as a reflector and the second half of the quarter wavelength antenna becomes present, as the image of the erected quarter wavelength vertical.

INPUT IMPEDANCE AND RADIATION RESISTANCE

As RF power is fed into an antenna, the energy is expended in two ways. Some of it is lost due to radiation. This is the loss that we want. The losses that we do not want, are the losses due to the resistance of the wire or tubing used in the antenna, the loss due to conduction in the insulators used to support the antenna, loss due to currents flowing in near by metallic objects, and losses because of corona discharge. If good quality wire, tubing and insulators are used, and the antenna is mounted away from other conductors, these losses will be kept to a minimum. The antenna design and shape of the ends of conductors will keep corona loss to a minimum. Corona loss is not normally a consideration until very high power is used.

There are two resistances to consider at the terminals of an antenna. We want all the power to go into the radiation resistance; this results in useful radiation. We want as little power to go into the Ohmic resistance as possible; this represents the losses that go into heat. The sum of these two resistances in an antenna is the impedance that the transmission line should be matched to for best efficiency. Rr is the radiation resistance, the useful part of the total resistance. Ro is the Ohmic resistance and represents the power lost as heat. The sum of these resistive values is Ra.

$$Ra = Rr + Ro$$

Ra represents the resistance of the antenna. Usually the Ro, Ohmic losses are so low that they can be forgotten. However in the case of the quarter wave vertical mounted at ground level, do not depend on ground alone or your losses due to heating the ground may become significant. Be sure to lay down radials to keep Ro as small as possible. Some antenna designs result in a very low value of Rr. As Rr becomes lower and Ro stays the same the percentage of radiated power will become less. Antenna arrays with closely spaced elements and physically short antennas are the ones that may have a very low value of Rr.

HARMONICALLY OPERATED DIPOLE

If a dipole is operated at a multiple of its design frequency, it is said to be operating harmonically. At even multiples of the design frequency, the impedance of the antenna at the feed point will be drastically different than at the design frequency. If an open wire transmission line and an antenna tuner are used, this can result in a very good multiband antenna system. The pattern of radiation will change from band to band, but great success with such an antenna system can be had. If the transmission line is coax cable, then losses in the cable can become objectionably high when the antenna is used on even multiples of the design frequency. At odd multiples of the design frequency, the current loops fall at the same points as at the design frequency and the feed point impedance may once again match the impedance of the cable (almost). Expect to be able to use a 7 MHz dipole on 21 MHz. However the resonant frequency of a 7.3 MHz

dipole will be about 21.0 MHz and the impedance will be higher than on 7 MHz. The VSWR will be a bit higher, but the antenna should be useful. The radiation pattern will be different (see section on radiation patterns). It is not practical to operate a quarter wavelength antenna on its harmonic frequencies because the radiation pattern will change and provide high angle radiation which is much less efficient in long range communications.

RADIATION PATTERNS

The simplest of antennas, the dipole, does have some gain. This is because it does not radiate equally well in all directions. Since little or no energy is radiated in some directions, (directly off the ends of the wires), the result is more energy is radiated in other directions. An electric bulb will radiate in all directions, (almost), but if a reflector is added it seems much brighter in some directions and dimmer in other directions. Thus when the reflector is added, it focuses the energy and gain is achieved. There are several methods of obtaining gain using antennas that will focus the energy in one direction at the expense of energy that would have gone in other directions.

The dipole is normally mounted horizontal. The horizontal radiation pattern of a dipole is shown on page 7. If the wire length is held fixed and the frequency is increased the pattern and current distribution will be changed as shown in the two bottom diagrams. Compare the first and second diagrams. The second diagram shows less area inside the pattern and thus has more gain. As the length of a wire antenna is increased, the gain increases and the number of lobes increases. The major lobe will move closer to the line of the wire but will never radiate directly off the end.

ANTENNA POLARIZATION

The polarization of the radiation from an antenna depends on the direction of the radiating element. Dipoles are normally horizontal and therefore have horizontal polarization. Quarter wavelength verticals will have vertical polarization. A single vertical is omnidirectional in the horizontal plane. At VHF, the polarization of signals becomes very important. The loss of signal strength, because of different polarizations, can be very significant. Normally on amateur VHF and UHF frequencies, FM stations use vertical polarization while CW and SSB stations use horizontal polarization. At HF, signals are propagated by refraction in the ionosphere. Once a signal is refracted, its polarization may be in any direction. The signal that starts out horizontal can come back to earth either horizontal or vertical, but will probably return at some oblique angle. Therefore, be concerned about polarization at VHF but not at HF.

GROUND EFFECTS

When we describe antennas and their patterns, we frequently use the term free space. It is usually easier to visualize antenna patterns in free space where re-radiation from other metallic objects and ground reflection or absorption cannot have an effect on the currents in the antenna, and cause pattern distortion. However, the antennas that we mount are affected by the presence of ground. At times, the ground is a reflector and at other times, it is an absorber. The ground around the base of a quarter wave vertical antenna needs considerable help in the form of radials, if this type of antenna is to perform well. When an antenna that is near ground radiates, some of the energy will strike the ground and some energy will be reflected. The reflected energy will bounce

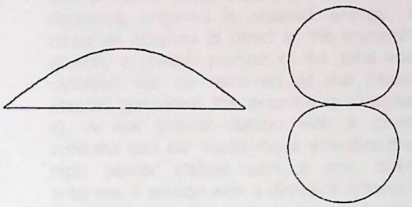
back to the antenna and effect the pattern of current distribution in the radiator, and thus effect the pattern and the feedpoint impedance of the antenna. The vertical angle of radiation, of horizontal antennas close to the ground, will be high if the antenna is within one quarter wavelength of ground. If communications on 80 or 40 meters is desired within a few hundred miles, this is an advantage. If the desired communication is DX (1000 or more miles) then low angle radiation is desired. On frequencies higher than the 7 MHz band low angle radiation is usually desired for best DX.

ADJUSTING ELECTRICAL LENGTH BY LOADING

The desire to have an antenna physically shorter than the electrical length leads us to loading an antenna with inductance. If a short (less than a quarter wavelength) antenna is operated, the reactance part of the input impedance will be capacitive. This reactance may be canceled by putting the same amount of inductive reactance in series with the antenna. If the losses in the inductance are kept small, by using large wire and a large diameter (2" or so), a very efficient vertical antenna can be made. Since an antenna has maximum radiation where the current is highest, the best efficiency will be achieved by putting the inductance further up the antenna. However when this is done, the inductance must be made larger. Any physically short antenna will have a relatively low feed point impedance. The feed point impedance will be raised, if the loading coil is placed further away from the feed point. If the feed point impedance is kept high, and Ohmic losses kept low, then the antenna will obtain a reasonably high efficiency.

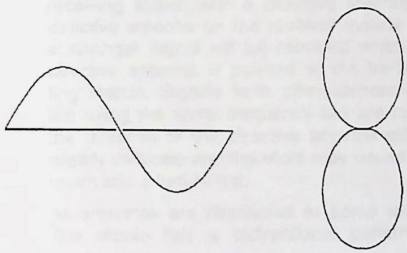
CURRENT DISTRUBITION

HORIZONTAL RADIATION PATTERN



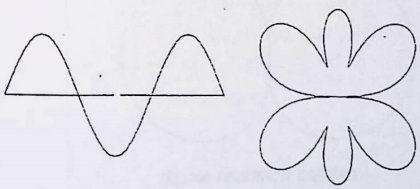
The following shows the current and pattern of an antenna at the design frequency and at 2 and 3 times the design frequency. The gap in the center of the wire in the current diagrams is the point where the feed line is attached.

The dipole is normally mounted horizontal. Current distrubution is shown by the curve above the line that represents the wire. Current flow must stop at the end of the wire. Normally the feed line is attached at the point of maximum current (minimum impedance) by spliting the dipole at the center. The horizontal radiation pattern is shown in the circle. Maximum radiation will be at right angles to the line of the wire.



When the frequency applied to the antenna is 2 times the design frequency the current and horizontal radiation pattern will be as shown. Notice that there is less area within the curve, this indicates that this antenna has more gain than the figure at the top of the page.

This antenna is refured to as a center fed full wavelength antenna.



When the frequency applied to the antenna is 3 times the design frequency the main lobe will split into major and minor lobes, gain of such an antenna is always referenced to the main lobe. This antenna will have more gain than either of the above antennas, but is not maximum at right angles to the wire.

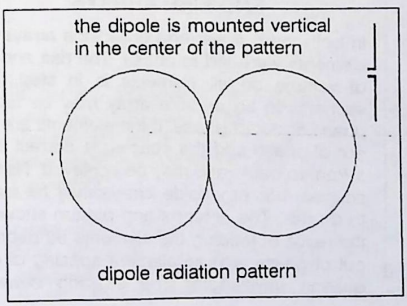
The length of this antenna may also be referred to as 3 half wavelengths.

GAIN AND DIRECTIVITY

The major consideration in radio communication is the transmission of RF energy from the transmitting antenna to the receiving antenna. Normally in amateur use this is communication from one station to one other station. Any RF energy sent by the transmitting station in any direction other than the direction of the receiving antenna is wasted energy. If a directive antenna is used at the transmitting station, a greater portion of the total energy radiated will be received at the receiving station, (provided the antenna is directed to it). A low power station with a directive antenna can be much more effective than a high power station with a non directive antenna. A station with a directive antenna will interfere with fewer other stations that may be using the same frequency.

The same reasoning may be applied to the receiving station with a directive antenna. A directive antenna on the receiver means that a stronger signal will be received when the directive antenna is pointed at the transmitting station. Signals from other stations that are using the same frequency but are not in the direction of the directive antenna will be greatly reduced and therefore may cause you much less interference.

All antennas are directional to some extent. The dipole has a bidirectional pattern as shown. The dipole is considered the basic antenna by which other antennas are compared. If a dipole and another antenna are used at a receiving site and the other antenna provides a greater signal strength in the receiver than the dipole then the other antenna has gain. The gain is expressed logarithmically (to base 10) of the ratio of the signal strength while on the other antenna compared to the signal strength when the dipole is in use.



Gain is measured in dB (decibels).

gain(dB) = 10 log (P2/P1)

Where P1 and P2 are two power levels.

In the example above P2 is the power delivered to the receiver terminals by the other antenna and P1 is the power delivered to the receiver terminals by the dipole.

If two dipoles are compared the difference is 0 dB since the ratio of 1/1 = 1 and the log of 1 is zero.

Another standard for measuring gain is the isotropic radiator. This is a theoretical antenna and in practice does not exist. Its value is that it radiates equally well in all directions. When the gain of an antenna is referenced to this radiator dBi is put after the gain value. If the gain is referenced to a dipole then dBd is put after the gain value. The gain of a dipole in reference to an isotropic radiator would be listed as 2.15 dBi.

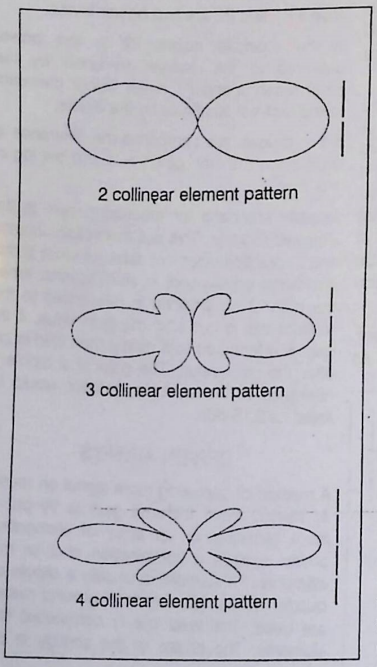
DRIVEN ARRAYS

A method of capturing more signal on receive or having more transmit gain is to put up more elements or an array of elements. A driven array is a combination of 2 or more elements. An element is usually a dipole or a quarter wavelength vertical if ground systems are used. The feed line is connected to all elements. The phase of the energy in each

element may not be the same. The desired end result is to make the radiation from one element and the radiation from other elements combine to create a radiation pattern that will provide a stronger signal in one direction and a null or weaker signal in other directions.

COLLINEAR ARRAYS

The collinear array consists of 2 or more elements placed along the same line, with the current in each element having the same phase. The figure shows arrangements using 2, 3 and 4 elements, mounted vertical. The gain of a 2 element array is 1.9 dB over a single dipole, for 3 elements it would be 3.2 dB and for 4 elements 4.3 dB. If the space between the ends of a two element collinear array were increased to .28 wavelength the gain would increase to about 3 dB.



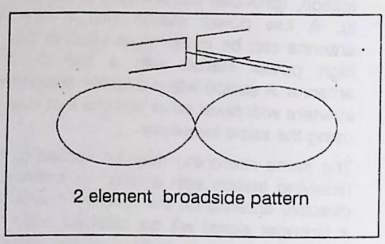
2 collinear element pattern

3 collinear element pattern

4 collinear element pattern

BROADSIDE ARRAYS

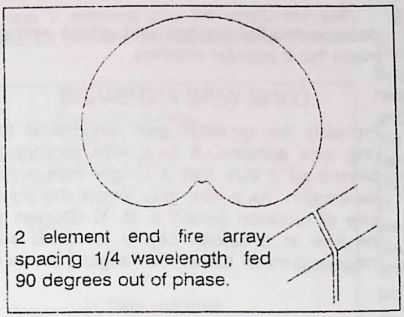
The broadside array consists of 2 or more dipoles arranged in the same plane and fed with the energy in phase at all dipoles. This arrangement causes maximum radiation at right angles to the plane the elements are in. The figure shows two elements mounted horizontal. Best performance is achieved when the elements are spaced 5/8 wavelength apart.



2 element broadside pattern

END-FIRE ARRAYS

In both the colinear and broadside arrays the elements were fed in phase. The rise and fall of voltage on all elements is in step. The elements in an end-fire array may be fed in phase or out of phase. If the elements are fed out of phase and the spacing is correct then a front to back ratio may be achieved. Neither collinear nor broadside arrays may be made to do this. The antenna and pattern shown is the result of feeding the elements 90 degrees out of phase with an element spacing of one quarter wavelength. The spacing between



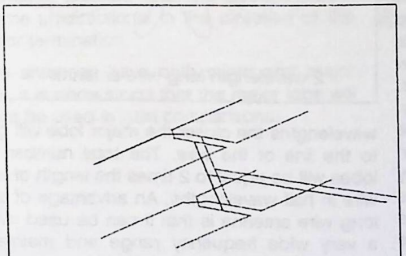
2 element end fire array, spacing 1/4 wavelength, fed 90 degrees out of phase.

elements as well as the phase of energy fed to each element may be adjusted and different radiation patterns will result.

COMBINATION ARRAYS

It is possible to combine arrays of different types into a larger and more effective array. Four elements may be combined into a combination of collinear and end fire elements with a gain of about 6 dB. Since the end fire elements are fed 180 degrees out of phase it is not possible to obtain a pattern with a front to back ratio, however the front to side ratio is very large. If one quarter wavelength spacing is used, fed with open wire line and an antenna tuner, this array can be used from the design frequency to one half the design frequency. The beam width of the pattern will not be the same over this frequency range but the direction of the pattern will not change.

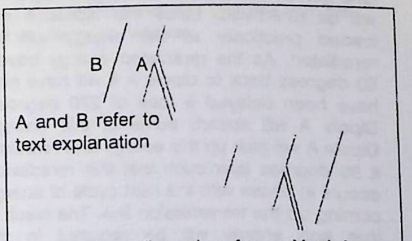
A combination of end-fire, collinear and broadside elements is possible as shown. The gain will be 7 to 8 dB depending on element spacing. Greater gain will occur with larger spacing.



8 element combination of collinear, broadside and end fire. each element is 1/2 wavelength, vertical spacing is 3/8 to 3/4 wavelength, horizontal spacing is 1/8 to 1/4 wavelength

PARASITIC ARRAYS

Another method of achieving gain is with parasitic elements. This is the most popular method of arranging elements into a beam. The dipole is the only element to receive power directly from the feedline. All other elements receive power because they are in



A and B refer to text explanation

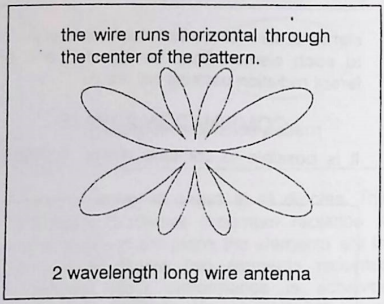
The usual configuration for a Yagi is one reflector, a driven element, and one or more directors. Maximum gain is in the direction of the director(shortest element). Starting with the reflector each element is about 5% shorter than the previous element.

the field of radiation of the dipole. The power in the parasitic elements will be delayed by an amount that depends on the length and spacing of the element and then re-radiated and used to reinforce the radiation from the dipole during the next cycle of power.

The addition of parasitic elements to a dipole is one of the most effective methods of improving its limited gain and directivity. The term parasitic element means that the power in this element arrived there due to radiation from the nearby fed dipole or other parasitic dipole. There is no direct connection from a parasitic element to the feedline. The figure shows two dipoles A and B. These dipoles are one quarter wavelength apart. Dipole A is attached to the feedline. Dipole B is a continuous unloaded dipole. As the energy that is radiated from dipole A passes dipole B it will create a current flow in this element. One quarter cycle later the energy in dipole B will be reradiated. Since this dipole is not loaded practically all the energy will be reradiated. As the reradiated energy travels 90 degrees back to dipole A it will have now have been delayed a total of 270 degrees. Dipole A will absorb some of this energy. Dipole A will pick up this energy and reradiate it 90 degrees later such that this reradiation occurs in phase with the next cycle of energy coming up the transmission line. The result is that less energy will be radiated in the direction of the unloaded element and more energy will be radiated in the opposite direction. This causes the unloaded element to act as a reflector and this is the name of this element. If another element that is shorter than the dipole is placed on the opposite side of the dipole from the reflector it will cause an even greater radiation forward and less energy to the rear. This new element is called a director. This type of array is call a Yagi-Uda. Uda did the original design work and Yagi was a Japanese professor who documented the findings and whose writings made this a popular antenna.

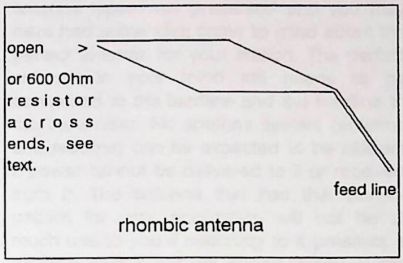
LONG WIRE ANTENNAS

Probably the simplest gain antenna is the long wire antenna. A long wire antenna is defined as a wire that is longer than a half wavelength. As a wire gets longer the major lobe of radiation (which is at 90 degrees to the wire in a dipole) begins to divide into major and minor lobes. The longer the wire in wavelengths the closer the major lobe will get to the line of the wire. The total number of lobes will be equal to 2 times the length of the wire in half wavelengths. An advantage of the long wire antenna is that it can be used over a very wide frequency range and maintain good efficiency. A typical long wire antenna pattern is shown. The length of the wire in wave lengths will determine the number of minor lobes in the pattern. If two long wire antennas are mounted so that the angle between them is equal to twice the angle that the major lobe is to one of the wires then two of the four major lobes will align and reinforce and the other two major lobes will be canceled. This arrangement is call a V antenna. This arrangement can be continued



2 wavelength long wire antenna

and one V antenna can be combined with another as shown. This is called a rhombic



rhombic antenna

antenna. The bidirectional pattern of the rhombic is caused by the reflection of energy off the ends of the wires at the end of the rhombic away from the feed point. If a resistive load were placed across the ends of the rhombic wires it would be called a terminated antenna and the pattern would become unidirectional in the direction of the resistor termination.

Some antennas have both minor and major lobes, it is understood that the major lobe will always be used in gain comparisons.

E AND H PLANE DETERMINATION

The patterns of antennas are defined as E-plane or H-plane. The line of direction of radiation is the common line in both E-plane and H-plane patterns. An E-plane pattern is the pattern that is in the same plane as the radiating element(s), it is in the electrostatic plane. An H-plane pattern is the pattern that is at right angles to the E-plane, it is in the electromagnetic plane. By referring to E or H plane patterns, confusion about whether the antenna is mounted for vertical or horizontal polarization is eliminated.

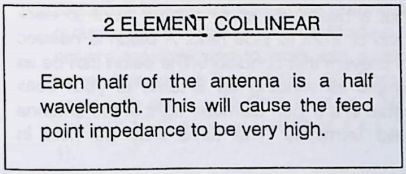
Money spent to improve an antenna system will improve both transmit and receive gain. Money spent to buy an amplifier to increase the transmitted power helps only on transmit. Your money and effort spent on improving antennas is by far the best value. The directive antenna can be looked at as a filter that will help eliminate or reduce in amplitude signals that might otherwise interfere with the signal you want to receive.

FEEDING AND MATCHING PRINCIPLES

In chapter two antenna radiation patterns and gain were discussed. The value of different antenna types was presented and you may have had some idea come to mind about the perfect antenna for your station. The perfect antenna in your mind still needs to be connected to the feedline and the feedline to the transmitter. No antenna system (antenna and feedline) can be expected to be efficient if power cannot be delivered to it or received from it. The antenna that has that perfect pattern for your application will not be of much use to you if matching to it presents a problem that is not yet solved. Many of the end-fire arrays, while presenting a very desirable pattern, will have a feedpoint impedance that results in a very low radiation resistance. Direct connection to a 50 Ohm cable in this case will result in very disappointing results. Your brand new antenna that just came out of the box has the potential to be just as disappointing if you mount it in an environment that greatly effects its feedpoint impedance.

RESONANT LINE MATCHING

A resonant line is one that operates with a very high standing wave ratio. The 2 element collinear array as shown will have a feedpoint impedance of 1000 to 4000 Ohms depending on the diameter of the wire and the environment in which mounted. Let us assume that the feedpoint impedance is 2000 Ohms. There is no practical feedline that will match to this high an impedance. One solution is to use a quarter wavelength of open wire feedline, one end connected to the antenna terminals and the other end attached to a low impedance feed line that connects to you transmitter. The open wire feedline will have a high standing wave ratio but losses in open wire line when operated this way do remain very low. The standing wave ratio in the low impedance line could be very low, therefore, losses in this line are kept to a minimum. A quarter wavelength of line is often used as a transformer to match high impedance antennas to a low impedance source (transmitter). The 2 element collinear array will be a dipole at half the frequency at which it is a 2 element collinear array. The feedpoint impedance then will be 50-70 Ohms and the quarter wavelength feedline is now one eighth wavelength. Now you do not have a match at either the antenna to open wire feedline or a match from the open wire line to the low impedance line. The most practical solution, if both frequencies are to be used, is to use an antenna tuner. Use open wire line, or at least 450 Ohm line, of what ever length is needed to go from the antenna terminals to the balanced output terminals of the antenna tuner.


2 ELEMENT COLLINEAR
Each half of the antenna is a half wavelength. This will cause the feed point impedance to be very high.

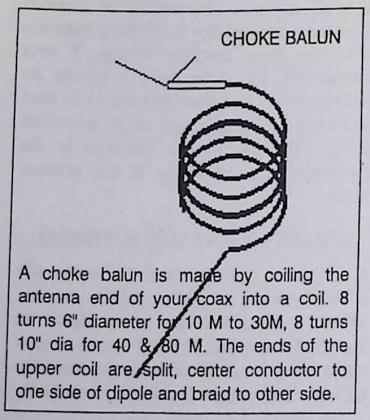
NON-RESONANT LINE MATCHING

A non-resonant line is one that operates with a VSWR that is 1:1, or at least a very low VSWR. Coax cable losses go up rapidly as the VSWR increases. The high losses in coax cable are a result of losses in the insulation between the outside braid and center con-

ductor plus the resistive losses in the center conductor and the outer braid. Open wire line uses air or mostly air as the insulator. Losses in air are extremely low which makes open wire line the better choice when other methods of matching the line to the antenna are very difficult. What is the best length to cut a coax feedline? This question continues to be asked and the answer is, as short as possible because that will have the least loss. Don't over do it or you could make other problems for yourself when later you decide to move the antenna or equipment, allow a little slack. When using coaxial cable it is important to have the antenna feed point impedance the same as the impedance of the coaxial cable; length then is not a factor.

USING A BALUN

The balun is a transformer used to match between a balanced load and an unbalanced load. The center fed dipole is a balanced load. The wire of the dipole is open at the center and both sides are the same. It makes no difference which antenna terminal you are considering since both are equally balanced from ground. The quarter wavelength vertical is an unbalanced antenna. One antenna terminal is the radiator and the other antenna terminal is ground. Coax cable is an unbalanced feedline and can feed a quarter wavelength antenna directly.



A choke balun is made by coiling the antenna end of your coax into a coil. 8 turns 6" diameter for 10 M to 30M, 8 turns 10" dia for 40 & 80 M. The ends of the upper coil are split, center conductor to one side of dipole and braid to other side.

Many amateurs feed dipoles from coax cable and get good results and lots of contacts. The VSWR should be reasonably low. The dipole fed in such a way is efficient and works well. Why then are we concerned about connecting balanced antennas to unbalanced feed lines? When you connect your dipole to a coax feedline by just soldering the braid to one side of the dipole and the coax center conductor to the other side of the dipole you are inviting current to flow on the outside of the coax cable. The current flowing on the outside of the coax has the potential to cause RF feedback and distort your audio while on phone or give your keyer problems when on CW. It may also be the reason that you sometimes feel a slight burn on your lip from the microphone or a funny feeling in a finger when you touch the key terminals or transmitter. If current is flowing on the outside of your coax it will also be radiating. If you have a horizontal antenna the radiation from it will be horizontal. However if the feed line is radiating you will now also have some vertical radiation. This vertical radiation can be the reason that a beam will show a poor front to back ratio or front to side ratio. A balun is needed to prevent this condition. The balun can be as simple as winding up 8 turns of your coax cable in a 6 inch diameter right at the antenna feed terminals. The turns may be held in

place with electrical tape or tie straps. This type of balun is called a choke balun. Baluns may also be made on a toroid core with wire windings. The toroidial baluns may be wound to provide either a 1:1 or 4:1 impedance transformation. If you buy a balun keep this in mind. For a dipole or Yagi with a split dipole feed you will want a 1:1 balun. Mount either type of balun close to the antenna terminals. Try to keep leads from the balun to the antenna elements fairly short (4 inches or less).

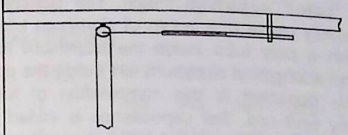
MATCHING TO DIPOLES

Most dipoles will have a center impedance between 50 and 70 Ohms when mounted at a practical height. 50 Ohm coax will provide a close enough match to the dipole. If the dipole has a 70 Ohm feed point impedance a VSWR of 1.4:1 will occur (this represents < a 4% power loss). This type of mismatch will not cause any modern transmitter any problems and the loss in the coax because of the standing waves will not be enough to be noticed. You may want to use either a choke balun or a toroidal balun on your dipole.

MATCHING TO QUARTER WAVELENGTH ANTENNAS

The quarter wavelength vertical with a good ground system will have a 36 Ohm feed point impedance and direct connection to 50 Ohm line will result in a VSWR of 1.4:1; this is a reasonably low value of VSWR and will not result in a significant loss in the coax cable or reduction in transmitter output. Modern transceivers are designed to work into a standing wave ratio of at least 1.5:1. 50 Ohm coax cable with either a 36 Ohm load or a 70 Ohm load will both show a VSWR of 1.4:1 (1.4 to 1).

GAMMA MATCH



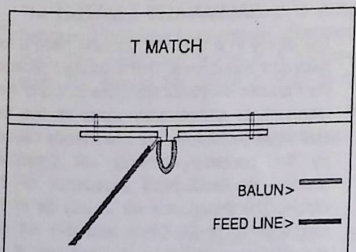
A typical gamma match is made with a length of aluminum tubing and an aluminum rod. The rod is inserted into a piece of poly insulation and then the combination is inserted into the tubing. This makes a capacitor. There are two adjustments, the amount of rod inserted into the tube and the tap point from the tube to the dipole.

GAMMA AND T MATCH

The dipole in a Yagi will normally have a low feedpoint impedance. This is caused because the parasitic elements are close to it and also resonant at a frequency close to the frequency of the dipole. The interference caused by the parasitic elements will drastically change the feed point impedance of the dipole. The impedance will usually be in the range of 10 to 20 Ohms and this will not make a good match to 50 Ohm line. If the dipole is not split in the center but is a continual piece of aluminum tubing, the center of the dipole can be directly connected to the boom. As you go out along the length of the dipole the impedance will become larger. At some distance from the center of the dipole the impedance will become 50 Ohms resistive and some value of inductance reactance. This would be a good point to attach our 50 Ohm coax if we could get rid of the

inductive reactance. Putting the same value of capactive reactance in series with this tap point will do the job. This method of matching is called a gamma match. The gamma is usually made of a length of aluminum tubing with a poly tube inside the aluminium tube and a length of aluminum rod inside the poly. The capacitor is this combination of tube, poly and rod. The capacitance is varied by adjusting the amount of rod that is inside the poly. A clamp between the dipole and aluminum tube allows the tap point on the dipole to be adjusted.

Another method of matching to a low impedance dipole is the T match. This is a balanced match and will therefore require a balun to be a part of the matching network when the antenna is fed with coax cable. Adjustment is done by adjusting the tap points on each side of the center of the dipole. Keep the tap point distances equal. The balun is a half wavelength of coax cable. This method of match is normally used only above 50 MHz.



A typical T match consists of the T and a balun that is made from one half wavelength of coax cable. The braid of the feed line and the braid from both ends of the balun are connected to the center of the dipole. The center of the feed line is connected to either side of the T match rods. Adjust the tap points on the dipole until a good VSWR is achieved. Keep the taps points the same distance from the dipole center. No series capacitor is required if you use a T-match.

QUARTER WAVELENGTH MATCHING TRANSFORMER

A quarter wavelength of transmission line will operate as a transformer. The impedance ratio is:

$$Z = \sqrt{(Zo*Zi)}$$

where

- Z is the impedance of the quarterwave transformer
- Zo is the output impedance
- Zi is the input impedance

If we are to match the collinear antenna previously shown to 50 Ohm line the steps are as follows:

$$Z = \sqrt{(2000*50)} = 316 \text{ Ohms}$$

Such a line could be built using the formula for transmission line impedance given in chapter one. The chart shows the range of practical impedances available from open wire line.

12 gauge wire spaced 0.5 inch has an impedance of 303 Ohms, this would be a practical transmission line to use. The better grade of 300 Ohm TV twin lead would also work. If this were a transformer for 28 MHz then the length of line would be:

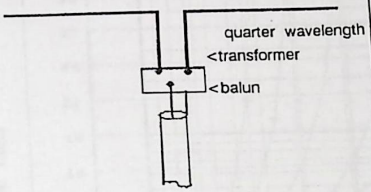
Length = [984/F(MHZ)]/4 to give one quarter wavelength (with air dielectric line). In practice the real length would be about 5% shorter.

Length = [984/28]/4 = 8.78 feet

Cut a length of open wire line 8.78 feet and attach it at the antenna terminals at the center of the radiator.

We have transformed 2000 Ohms to 50 Ohms but to go into coaxial cable we need to add a balun to transform the balanced impedance of the open wire line to the unbalanced input of the coaxial cable. The 2 element collinear array and feed system now looks like this.

2 ELEMENT COLLINEAR



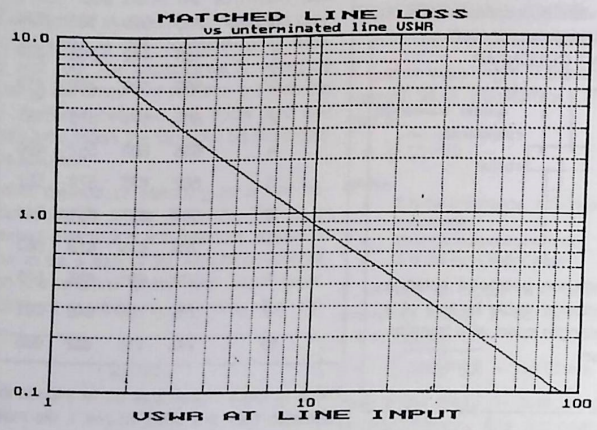
A high impedance balanced antenna matched to coaxial cable by use of a quarter wavelength open wire transformer and balun.

Sinclabs, of Aurora Ontario, uses a unique matching method involving a quarter wavelength of 35 Ohm coax wound into a choke balun. Their SY20-3 twenty meter three element split dipole fed Yagi has a 24 Ohm feed point impedance. The quarter wavelength of coax transforms the feed point impedance to 50 Ohms. The coiled coax acts as a choke balun and transforms the balanced feed at the antenna to an unbalanced feed ready to connect to your coaxial feedline. Carefull design plus proper matching allows this antenna to cover the entire band with low VSWR.

OPEN WIRE TRANSMISSION LINE IMPEDANCE VS SPACING

GAUGE	18	16	12	8
SPACING INCHES				
0.5	386	359	303	246
1	469	442	386	329
2	552	525	469	413
3	601	574	518	461
4	635	608	552	496
5	662	635	579	522
6	684	657	601	544
7	702	675	619	563
8	718	691	635	579
9	732	706	649	593
10	745	718	662	605

There is more signal loss do to impedance mismatch than any other source. I, like most hams, measure the VSWR at the input to the transmission line next to the transceiver. It is most convenient to measure it there. What really happens to line loss and real VSWR is presented with the next three graphs. Take time to understand these graphs and then reduce your losses by proper matching.



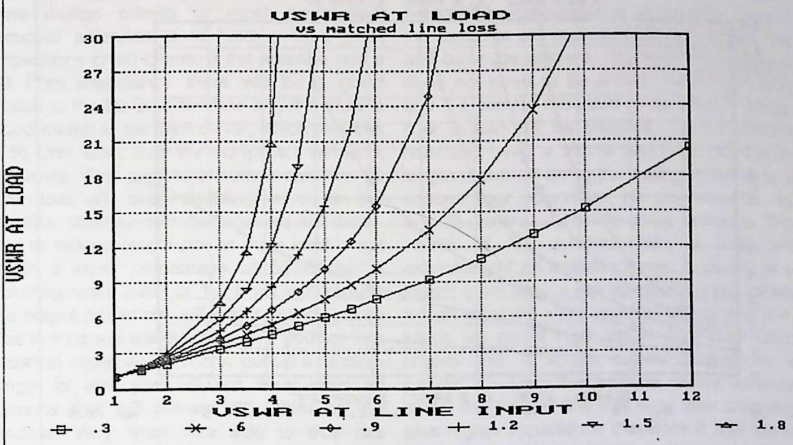
Measure the VSWR on an unterminated line.

Example:

if the VSWR is 10:1 then enter graph at bottom at 10.

Go up to curve.

Read on left scale that matched line loss would be .87dB.

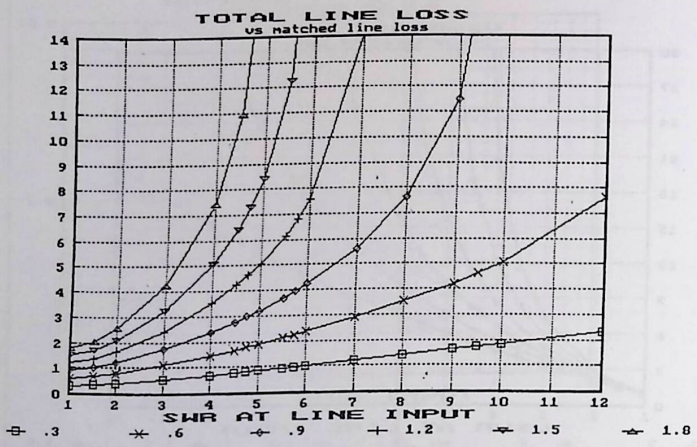


Assume that the matched loss is .6 dB and VSWR at transmitter end of coax is 6:1.

Enter graph at bottom at 6.

Move up graph to curve that represents .6dB.

Read on left scale that VSWR at load is 10:1



Assume that the matched line loss is .9 dB and the the VSWR at the transmitter end of the line is 5:1.

Enter graph at bottom at 5.

Read up graph to curve that represents .9 dB.

Read on left scale that total line loss is 3.2 dB.

ANTENNA IDEAS

Because of restrictive covenants or temporary rental or other circumstance it may be impossible to erect an outside antenna. Ham Radio communication is still possible with a little planning and help from antenna tuners. One design criteria of most commercial Amateur antennas is to have a feed point impedance of 50 Ohms. If the antenna has a 50 Ohm impedance there will be a good match to the 50 Ohm feedline and therefore a good match to the transceiver, which requires a 50 Ohm load, thus the equipment will work efficiently. Any departure from a resistive 50 Ohm load will cause standing waves on the feedline. Most modern transceivers are designed to reduce output power if the load is not within a small percentage of 50 Ohms. A standing wave ratio of 1.5:1 will not reduce the output power nor will it significantly cause loss in a coaxial cable feed line. If you are in a situation where you can only put up a random length of wire you will not likely have an antenna that will present 50 Ohms to the feedline. Very small wire #30 to #36 has been used successfully to make outdoor antennas that are practically invisibly. Antennas made with very small wire are more subject to breaking and should be mounted so that if they fail they will not fall into an area that will be the cause of concern for others. Modern antenna tuners have the capability of accepting almost any value of resistance and reactance and transforming that value to a 50 Ohm load so that the transceiver will be able to operate efficiently. If you have a random length wire antenna that the tuner fails to load just change the length of the antenna a bit and try again.

BALANCED ANTENNAS

A balanced antenna is fed at the center with either a parallel line or coaxial line with a balun. The most popular balanced antenna is the half wavelength dipole. One of the reasons for its popularity is that the antenna has a center impedance near 50 Ohms when mounted in the presence of ground. Only if the dipole is self resonant will the coaxial line and balun be efficient. However, this antenna does not need to be a half wavelength long and if it can be mounted in an attic or upper floor in can still be effective. I know of one ham that used a dipole less than 35 feet in length mounted along the ceiling molding in a second floor apartment. He operated 20, 40 and 75 meters and made many contacts. The secret of his success was a balanced antenna and an antenna tuner. A dipole of a length other than a half wavelength will cause a high standing wave ratio on the coaxial line, which will cause high losses in the 50 Ohm coaxial line. A simple solution is to use a parallel line from the antenna to the antenna tuner, the parallel line has very little dielectric plus higher impedance therefore it has lower loss even at a high VSWR. In the case of the second floor apartment ham he didn't even use a parallel line since the distance from the radio equipment to the antenna was only from the desk to the molding at the ceiling; he just ran the antenna wires from the output of the antenna tuner labeled "BALANCED LINE" until they arrived at the ceiling molding, from there the wires went in opposite directions along the molding around three sides of the room. He in effect made a parallel feed line of a portion of the wire used for the antenna. This system worked well because he kept the antenna balanced which greatly reduced the need for the radio equipment to see a good RF ground.

UNBALANCED ANTENNAS

Unbalanced antennas consist of the random wire type and are usually fed against ground. If you are in a basement or first floor apartment where you are close to ground you may be able to use that to advantage. If you can run a wire along the outside corner of a building to the eve you have a vertical that may be fed against ground. If you have a townhouse you may be able to run a wire from the first floor up to the highest point in the loft. An antenna does not have to run in a straight line and may have bends in it; however, keep the bends to a minimum and try to avoid sharp bends. The longer the wire can be the better, up to 5/8 wavelength. In this situation you would use the unbalanced output of the antenna tuner and the best ground connection that you can get. (Also see artificial grounds in chapter 5.)

USING A RAIN GUTTER AS AN ANTENNA

Metal rain gutters and down spouts can be put to use as antennas. Make sure that there is a good metal to metal contact between sections. It may be necessary to install self-tapping screws between gutter and down spout sections to insure low resistance connections from one section to another. If this is a new rain gutter installation you may have the option to arrange the sections to favor a balanced antenna.

USING A LIGHTNING ROD AS AN ANTENNA

A lightning rod will have one end grounded. If it is a deep ground it could have some help with radials along the ground connected to the rod at ground level. To match to this antenna a connection must be made a some level above ground, hopefully near a 50 Ohm point. A matching network will be needed and the configuration of this network will depend on the length of the lightning rod and the frequency that you want to use. Do not use a lightning rod that is longer than 5/8 wavelength if you want to work DX, or you will end up with high angle of radiation.

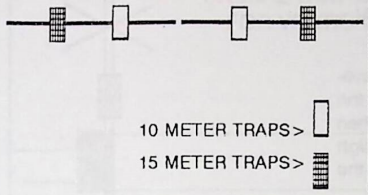
RANDOM LENGTH WIRE ANTENNA

Using a wire that is outside and away from other conductors will likely provide the better performance than the rain gutter or lightning rod. You may use a wire that is very small and therefore not likely to be noticed. One end of the wire should connect directly to the terminal labeled "WIRE" on the back of the antenna tuner. With this type of antenna a good connection to ground is very important. Try to make the wire length as long as possible. Some wire lengths may present an impedance to the tuner that is beyond the capability of the tuning circuits. If some frequencies work and others don't then adjust the length of the wire by a few feet and try again.

MULTIBAND ANTENNAS

TRAP DIPOLE

The ideal antenna will have a 50 Ohm resistance at all frequencies that you wish to use. One way to achieve this on multi-frequencies is by use of traps. A trap is a parallel resonant combination of inductance (coil) and capacitance (capacitor). If the reactance of both the coil and capacitor are the same then it is resonant and will have a



The trap dipole is an example of a balanced antenna. This example shows traps for 10 and 15 meters. The overall length tunes the antenna to to lowest frequency band to be used.

very high impedance. This high impedance will act like an insulator. In the dipole pictured (next page) the first trap from the center of the antenna is tuned to the 28 MHz band (10M). At this frequency, the end of the wire as far as conduction is concerned is this trap. The length of wire from the center of the dipole to the trap is one quarter wavelength. Therefore we have a half wavelength antenna and the impedance is close to 50 Ohms.

Now lets look at what happens at 21 MHz (15M). The second trap is tuned to the 21 MHz band, and therefore this trap is the end of the antenna at that frequency. The length of wire from the center of the antenna plus the inductance of the 28 MHz trap plus the length of wire from the 28 MHz trap to the 21 MHz trap is now electrically a quarter wavelength. Again we have a half wavelength antenna and the impedance is close to 50 Ohms.

At 7 MHz (or some frequency lower than 21 MHz) no trap is needed. The overall length of wire from the center of the dipole to the first trap, plus the inductance of the first trap, plus the length of wire from the first trap to the second trap, plus the inductance of the second trap, plus the length of wire past the second trap makes an electrical quarter wavelength, when 7 MHz energy is fed to the antenna. Again the impedance is close to 50 Ohms.

If more bands were wanted more traps could be included. A multiband antenna of this type will always have one less trap than the number of bands that it will tune. I am counting only the traps on one side of the antenna. The other side must be constructed identically to the first side. Some antennas use the word "resonator" instead of "trap".

TRAP VERTICAL

A popular method of building vertical antennas is by using this same approach. Only half of the antenna is needed and aluminum tubing is used instead of wire. Many manufactures use this method. The first trap from the bottom will be for the highest frequency band, normally 28 MHz. In order as you continue to go up the antenna will be the 21 MHz trap, 14 MHz trap and the 7 MHz trap. The tuning of this type of antenna is started at the highest frequency band. Measure VSWR at each end of the band of frequencies you want to use. If VSWR at 28 MHz is 1.1:1 and the VSWR at 28.8 MHz is 1.6:1 then the antenna favors the lower frequency and should be shortened slightly. Adjust the length of tubing just below the trap for the band that you are measuring. Repeat this for all the other traps. For the lowest band adjust the length of tubing above the top trap.

An antenna of this design will cover all of the 10, 15 and 20 meter bands. On 40 meters it will give you a good VSWR over about 1/3 to

TYPICAL CONSTRUCTION FOR VERTICAL ANTENNAS

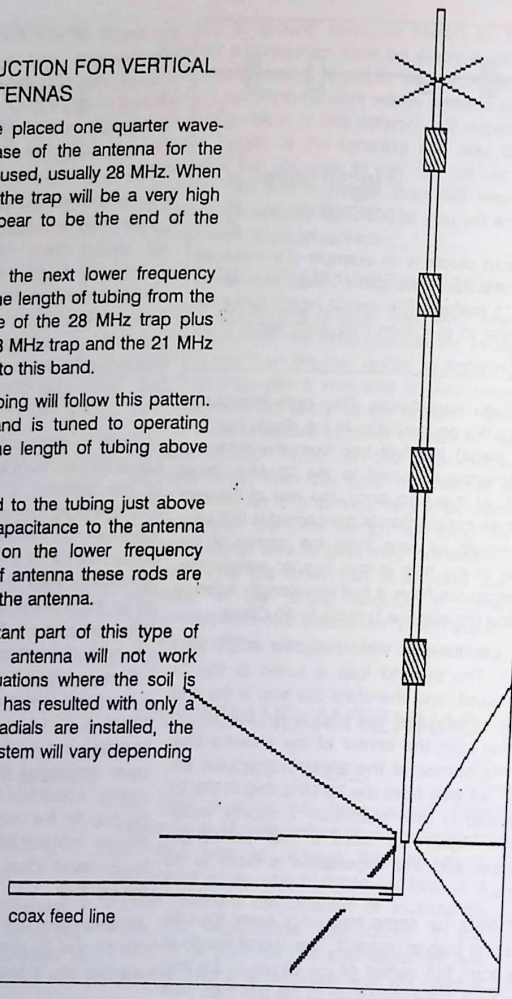
The bottom coil will be placed one quarter wavelength up from the base of the antenna for the highest frequency to be used, usually 28 MHz. When operating on this band the trap will be a very high impedance and will appear to be the end of the antenna.

The next trap up is for the next lower frequency band, usually 21 MHz. The length of tubing from the base plus the inductance of the 28 MHz trap plus the tubing between the 28 MHz trap and the 21 MHz trap will tune the antenna to this band.

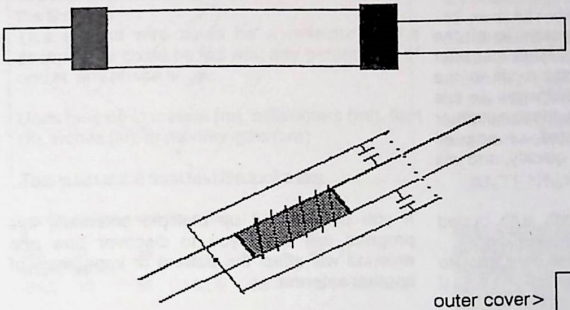
All the other traps and tubing will follow this pattern. The lowest frequency band is tuned to operating frequency by adjusting the length of tubing above the top trap.

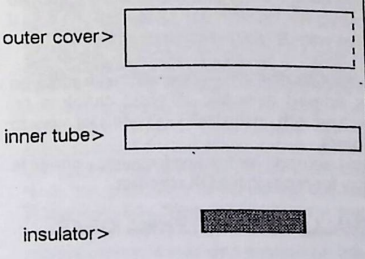
The top hat rods attached to the tubing just above the top trap are to add capacitance to the antenna and improve bandwidth on the lower frequency band. On some models of antenna these rods are attached to the very top of the antenna.

Radials are a very important part of this type of antenna; the quarterwave antenna will not work without them. In some situations where the soil is very damp good operation has resulted with only a short ground rod. If no radials are installed, the efficiency of this antenna system will vary depending on the dampness of the soil.



TYPICAL TRAP CONSTRUCTION
FOR VERTICAL ANTENNAS





An insulator is wound with wire to form a coil. The ends of the coil are attached to aluminum tubing on each end of the insulator. The outer cover for the trap is a larger size of aluminum tubing. The lower part of the outer cover is attached to the lower aluminum tubing. The upper end of the outer cover is insulated from the upper aluminum tubing. The space tnat is common to the upper tube and the cover creates the capacitance to tune the trap to the operating frequency. The outer cover is moved along the trap until the trap is tuned to the correct frequency. Then a self tapping screw is inserted to hold the cover in the correct place.

1/2 of the band. As an antenna becomes shorter, but resonance is maintained with loading coils as in this case, the useful VSWR bandwidth becomes smaller. On the 80 meter band the useful VSWR bandwidth will be 60 to 100 KHz.

RADIALS

Be sure to use as many radials as suggested in the instructions that came with your antenna. The use of more radials will improve performance. The advantage of more radials above 20 becomes rather minimal. If a multiband vertical is mounted above ground, the radials should be one quarter wavelength. The ends of the radials need to be insulated.

If this antenna is mounted at ground level, the radials may be shorter and may be buried under ground. Use a lawn edger to cut a slit in the ground in which to push the radial wires. In this case, no insulator is needed. You may use either insulated or bare wire. Insulated or enamel covered wire will not corrode as quickly, and will therefore last longer when buried.

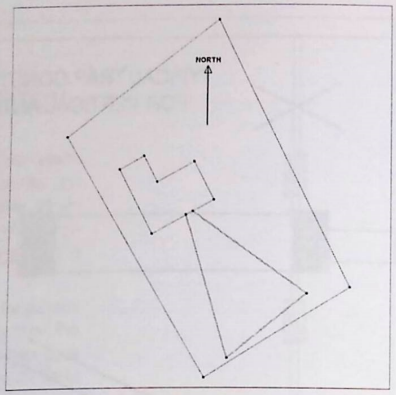
For a multi-band vertical antenna with buried radials, use 16 to 20 radials 20 to 30 feet long.
(0.1 wavelength long at the lowest frequency to be used.) . Wire size from #12 to # 22 will do. If you have very dry soil, use more radials.

The latest (2007) ARRL Antenna Book has seven listings spread over five different chapters on radials. A search on the WEB will add a lot more to this subject.
A vertical antenna for the low frequency bands is a favorite for many in the DX contests.

EVALUATING ANTENNA IDEAS

A program that I use frequently is EZNEC by Roy Lewallen, W7EL.

All the plots in this book were done using Eznec. This program will show the radiation pattern, the impedance of the antenna, and the SWR bandwidth and much more. When I get an idea to try, I use Eznec to discover if it is practical. While it was not intended to be used to show plat and house outlines, it works for this also. This is the diagram of my lot, house and the 80 M loop antenna.



If you plan to put up multiple antennas, this program will allow you to discover how one antenna will affect the pattern or impedance of another antenna.

At one time, I laid out five antennas using this program. Each antenna by itself seemed to be a good idea. The interaction to the antenna in use, by the other wires, really destroyed the value of wire in use. Providing greater distance or different orientation of the wires may make big differences. Eznec will allow you to be aware of these potential problems.
To define an antenna, you need to lay out the X, Y and Z position of each end of the wire.
Example: ft;
Any text after a semicolon is a comment. ft states that you want to use feet as the measuring unit.

-33 0 35 33 0 35 11 ;
the last number is optional, if used it specifies the number of segments in that wire.

In the X direction, east and west, the wire is 66 feet long.

In the Y direction, north and south, the wire is at 0 everywhere.
The height of the wire is 35 feet (Height is "Z" direction).
If a second line were added:

-33.5 33 35 33.5 33 35 11

This shows a second wire spaced 33 feet in the Y direction from the first wire, and it is longer than the first wire.
This second wire could be a reflector or the second wire could be fed with any percentage of and at any phase angle.

Units may be in meters (m), millimeters (mi), feet (ft), inches (in), or wavelengths (wa)

This is what the final text file looks like.

```
; Antenna name and any notes
ft
-33     0       35      33      0       35  11
driven element
-33.5   33      35      33.5    33      35 11 ;reflector
```

When importing text files you may replace or add to wires already present. This allows you to evaluate the effects of other antennas nearby.

You can place resistive or reactive loads, or combinations in any segment, in a wire. The term "Wire" also applies to tubing. Transmission lines can be evaluated.

Eznec outputs:

horizontal, vertical, and three dimensional patterns
Impedance
VSWR bandwidth
A wire model of the antenna(s) that can be rotated in 3D.

There is an option to adjust the conductivity of the soil that you have.

The ARRL Antenna Book now includes EZNEC-ARRL. This is a W7EL version of his antenna program. The segments in this program are limited to 20. It is adequate for evaluating a single wire antenna, but not for evaluating multiple wires and their interaction.

GROUND SYSTEM

To make a horizontal balanced antenna work well, no ground is needed. However, do think about lightning protection.

The ground system I use is three 8 foot ground rods, spread over a distance of about 26 feet. Also there are four 4 foot ground rods in this distance. All of these are connected together with #8 wire. All rods are driven, so that the top of the rod is below grade with the exception of the rods holding lightning arrestors. I use the 80 M loop antenna on 160 meters, by connecting the leads of the 450 Ohm line together at the transceiver, and feeding this against the ground system. This has worked well for me.

ANTENNA FEEDTHROUGH PANEL

Above is the feed through panel that solves the problem of getting feedlines outside. I used #14 solid wire, striped from house wiring. The stiffness holds them in place, so that there is not a change in impedance caused by wire movement. Note the grounding switches for the feedlines. These switches allow me to select a single wire antenna or the 450 Ohm feed line. There are lighting arrestors outside mounted on the ground rods, but the best policy is to remove the feed to the transceiver and ground the feeders. Protect your expensive radio equipment.

TREES AS ANTENNA SUPPORTS

The ARRL Antenna Book suggests using a pulley and counter weight to allow for the varying distances between trees caused by wind. At a former QTH, I noticed that in very gusty conditions, sometimes the support trees moved in opposite directions, at the same time. I decided

to make my counterweight out of an eight foot length of 5/16" chain. Put about half of the length of the chain on the ground during no wind conditions. This prevents the chain from swinging in the wind. Now as the wind moves the trees, more or less of the chain gets lifted off the ground. This gives a gradual increment in the weight of the counterweight.

At the corners, of the loop antenna, provision needs to be made to allow the wire to slip as trees move. I used a 1 inch PVC coupling. If you plan ahead, it can be put over the wire before the loop is

completed. If you forget, as I did, then cut a slit in the coupling so that it can be put over the wire. Align the slit away from the wire and use a piece of rope (double or triple wrapped around the coupling). The other end of this rope goes through the pulley and then to the weight. The rope I used is UV-resistant Dacron double weave rope. 3/32", 260# breaking strength.

I made cleats of two pieces of 1 inch board and fastened them to the trees with screws. The end of the rope that goes to a pulley is wound on this cleat. This cleat also holds a loop of rope that goes over the support limb. This loop can be used to replace the rope that goes to the pulley should it break. The cleats are mounted about 10 feet above ground to put them out of reach to others. They are reached by using a step ladder.

Trees have limbs that fall off. This happened on a windy day to my loop antenna. A limb came down pulling one leg of the loop to the ground. I had a few QSOs before I removed the limb. The wire went back up, no damage done. The chain weights did their job.

A six inch snow fall gave me a chance to see the action of the wires due to the added weight of the wet snow. The wires sagged, the weights came up. The antenna worked just fine after retuning. After the snow dropped off, the wires returned to normal height, about 25 feet.

ALL HF BANDS WITH AN 88 FOOT DIPOLE

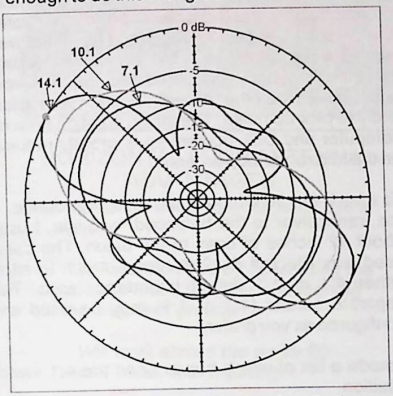
An 88 foot dipole is not resonate on any of the HF bands. This means that using coax to feed this antenna, is not a good idea. The high VSWR will cause a large loss of power in the coax. There are ways to solve this problem. The use of open wire line or ladder line are good choices. I chose to use 450 Ohm ladder line. Other choices: 300 Ohm ladder line, or 00 quality TV line, if high power is not anticipated.

Ladder line and open wire line are balanced lines. The output impedance of our transceivers are 50 Ohms unbalanced.

The Elecraft K1 transceiver, I was using, did have an internal ATU. I choose to bypass this tuner and use an external antenna tuner. I was using a Z-match tuner that does have an output link, that provided a balanced output. Some Z-match tuners even have two output links and a switch allowing you to choose a low or high impedance output.

Balanced output tuners, such at the MFJ-974HB and MFJ-976 legal limit tuner have true balanced output circuits, and are excellent choices.

The 88 foot dipole, when used on 14 MHz, is called an Extended Double Zepp (EDZ). The radiation patterns for 40, 30 and 20 meters are in the diagram. I aligned the antenna to favor 300° azimuth. If possible, align the dipole to favor the direction you most want to contact. I was lucky enough to do this with great results.



We usually are not concerned with the exact length of the antenna or the feedline. If you want to keep the radiation pattern you designed, do not make changes in the antenna length. If a problem in matching with a tuner occurs, the transmission line length may be changed in small increments until a match is found. I did not find that this was necessary. Best length for a feedline is usually about 1/8 wavelength for the lowest frequency band. (Also see the ARRL antenna book.)

I used this antenna on 40, 30, 20 and 17 meters, the only bands that the K1 covered. I was very satisfied with the results. However, this antenna would work well from 80 to 10 meters.
If mounted at a height of 30 feet, the radiation will be mostly at high angles on 80 and 60 meters, making it an NVIS (Near Vertical Incidence Skywave) antenna. This is most useful for contacts on 80 and 60 meters out to several hundred miles. Great for area wide nets! As frequency increases the elevation angle of maximum radiation will become lower.

An 88 foot dipole. on 80 meters, will be -0.5 dB down from a full size dipole for this band. An insignificant loss for the use of a shorter antenna. A full size dipole for 80 meters, fed with coax cable, will not cover the full band due to limited SWR bandwidth.

80 M HORIZONTAL LOOP ANTENNA

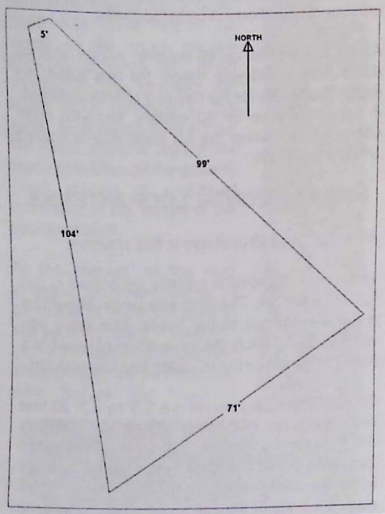
Actually I used 85 m of wire in this antenna.

The Loop Sky-wire is usually described in the form of a square. The total wire length should be a full wavelength at the lowest frequency you want to use. This is the description of how I fit a horizontal loop on my lot, using trees for support.

On the back of my house is a 5.5' by 2.5' 20 feet high enclosure that has a chimney in it. Across the top of this structure I put a pressure treated 2x4 to support the ladder line insulator. The wires from the center insulator go out through holes near the ends of the 2x4 and then to the trees at the back of the lot. The antenna wire I chose is 18AWG (OD 0.0445") "Silky" 40% copper-clad steel conductor (Nominal OD, 0.090" including 0.020" jacket). This wire has low visibility and is rugged. (Great for neighborhoods with covenants.)

If there is a possibility of the wire touching branches, use insulated wire.

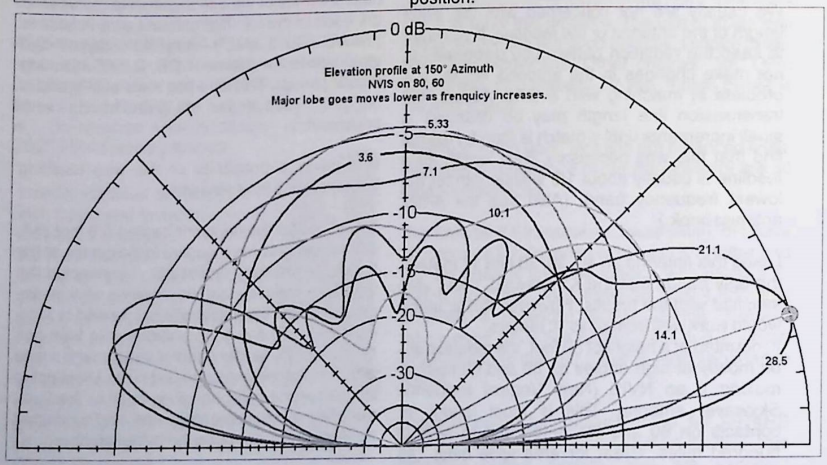
First, I put up the pressure treated 5.5 foot 2x4, with ladder grabber mounted in the center, at the top of the chimney enclosure. I connected the feed line. Initially I laid the antenna wire on the ground below the points where I wanted to raise it. Then I connected the antenna wire from one terminal of the ladder grabber and through a hole in the end of the 2x4 to the first point. I kept going to the second point and then back to the 2x4 , through the hole in the other end and connected it to the other terminal on the ladder grabber.



When I started to use this antenna I found some surprises. When you connect an antenna to your radio you expect to hear some noise, which just proves you have made all the connections. I made connection to the new loop antenna, turned on the transceiver and listened. Nothing. I switched to another antenna, noise. Then I tuned to a 40 meter net and heard signals. I switched to the horizontal loop, signals went up 2 S units and the noise went away. I used the antenna this way for a few days and then went back and raised one corner. A week later I raised the other corner. A loop of wire is less likely to pick up noise. The stray radiation from my computer and DSL equipment is greatly reduced on the horizontal loop antenna.

To match the 50 Ohm unbalanced impedance, of the transceiver to the balanced feed line, I used about 12 inches of coax to the balun. The balun used was Elecraft BL-2. It has a switch to allow either 4:1 or 1:1 output impedance ratio. Two separate baluns (4:1 or 1:1) may be used and configured as you prefer.

I made a list of which bands need the 4:1 switch position.



I did a Google search using "wet ladder line" as the subject. There were many hits on this subject. Over the winter my ladder line was laying on the ground under wet leaves. Altho Laying ladder line on the ground is not good engineering practice, I made many contacts,

including DX Stations. I now have the ladder line in a 1" PVC pipe, about 30" off the ground. This helps keep the line dry.

HORIZONTAL LOOP ANTENNA ADVANTAGES

Multiband coverage, but must use a tuner.

Will work on 160 by connecting the feedline leads together and feeding them against ground.

Will work across the entire 80 meter band, with retuning.

Usually less noise pick up.

Good NVIS coverage on the low bands and low angle radiation on the high bands.

It fits my yard and the #18 insulated wire is difficult to see from the street.

Can use trees to support the wire.

May be put up by one person over a period of days.

You can start using it as soon as the feed line is attached to the loop of wire and raise the ends latter.

Low cost, mast or tower not needed (if you have trees).

On 80 and 60 meters this is a perfect NVIS antenna. On 40 meters the vertical lobes start to come down. I have had very good results on 40 with net operations and general contacts. On 30 meters and above in frequency I have had DX respond to my CQ.

For an antenna that is in use from 160 to 6 meters I am pleased with the results. The antenna is low in visibility. Only one neighbor noticed the wire and I explained what it was used for. It has survived limbs falling and snow loads. For general coverage across so many bands it has given me a great deal of operating pleasure.

GRASS WIRE ANTENNA

Are you really anxious to get on the air? Try a "grass wire" antenna. I laid out 150 feet of insulated wire on the ground. I had part of my ground system in. I fed the "grass wire" against the ground and got on the air. I was making contacts. That solved my need to "do it now". Such a wire does work but your performance will be 3 to 4 S units or more below a good wire up in the air.

If you have a wooden fence six feet high to put this wire on you will gain about 6 dB, going to ten feet high you get 3 dB more. This is for the 80 m band.

OBTAINING PARTS

The antennas I have described are do-it-yourself projects. I already had many items available. If you are just starting your first antenna project, here are some suggestions to help you find the parts.

Also look in the pages of QST and CQ magazine.

WIRE:
The Wireman has given me good service and has a wide selection of insulated wire.
My selection for all antennas described, was 18AWG (OD 0.0445") "Silky" 40% copper-clad steel conductor (Nominal OD, 0.090" including 0.020" jacket). If you need real invisible they also have a #26 wire.

For bare wire MFJ now offers flexible 7 strand, and solid 14 gauge wire.

LADDER LINE:
MFJ and The Wireman.

LADDER GRABBER:
Emtech and MFJ

ANTENNA END INSULATORS
MFJ and THE WIREMAN.

FEED THROUGH PANEL:
MFJ Has several from which to select.

DACRON ROPE:
MFJ and THE WIREMAN.

GROUND RODS AND CLAMPS, #8 WIRE, AWNING PULLY

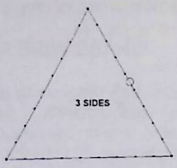
LOCAL HARDWARE STORE.

BALUN:
ELECRAFT (BL-2)and MFJ (MFJ-911H) offer BALUNS that ARE switchable 1:1 and 1:4.

More on baluns in chapter five.

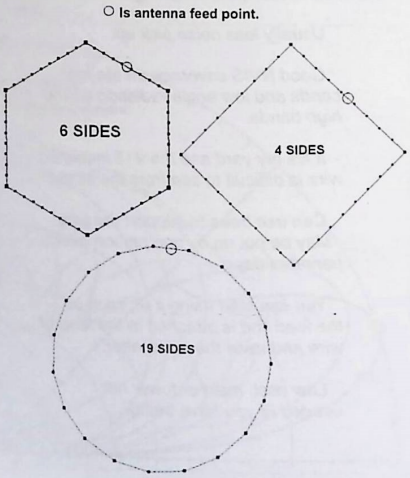
I wondered about the value of more sides to the horizontal loop. I ran loops with 3, 4, 5, 6, 7, 19 and 64 sides, all with the same height and wire length. My unequal sided loop, modeled at 8 m showed 5.2 dBi.

SIDES	GAIN
3	5.38 dBi
4	5.69 dBi
5	5.82 dBi
6	5.93 dBi
7	5.99 dBi
19	5.98 dBi
64	6.01 dBi



Other technical writers have suggested using a square pattern for a horizontal loop antenna.

I was able to use trees where they were. I am pleased with the great NVIS coverage I get on 80 and 60 meters. I have been pleased with the results on all bands 160 to 6 meters.

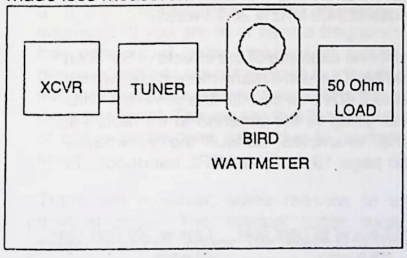


EQUIPMENT REVIEW

USING ANTENNA TUNERS

Antenna tuners are not to be considered power consuming devices that reduce the output power that you might otherwise have. Rather they will allow you to use an antenna that may not present the proper impedance to your transceiver (transmitter). They will let your transceiver see a correct load so that the transceiver may operate efficiently. Most antenna tuners have a selector switch position so that the tuning circuits may be bypassed when not needed. Using an Antenna tuner at the equipment end of your feed line is not a free ride however. The amount of mismatch that you let the antenna tuner compensate for will determine the amount of EXTRA loss in the feed line. This discussion is about coax feed lines, there is very little extra loss due to using open wire or parallel feed lines at high standing wave ratios.

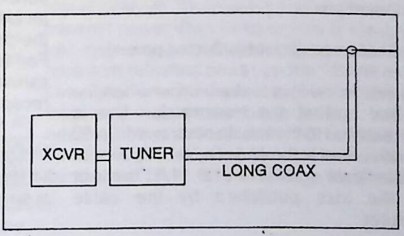
To put using an antenna tuner in perspective I made loss measurements on an MFJ-949C.



The tuner was adjusted for minimum VSWR, then power measurements were made with and without the tuning circuit in the line to the dummy load.

Freq	Direct	Thru tuner	Loss
	Watts	Watts	(dB)
1.815	33	26	1.03
3.815	33	29	.56
7.20	32	30	.28
10.12	33	32	.13
14.12	34	32	.26
18.12	34	33	.13
21.12	35	34	.12
24.94	34.5	34	.06
28.7	35	34	.12

The loss due to using an antenna tuner is so small that it can be ignored. However there is another loss, not the antenna tuner's fault, that does creep in. With the following set up a dipole cut for 40 meters is put to use on all bands by way of an antenna tuner and 75' of RG-58 coax. I do not recommend the use of RG-58 except for short runs between equipment or in mobile operation. The loss using RG-8 or RG-213 is somewhat less.



Something very different is happening now.

SWR

FREQ MHz	SWR	MATCHED LOSS dB	TOTAL LOSS dB
1.9	99.0	0.5	8.3
3.7	99.0	0.7	9.5
7.1	1.4	0.9	0.9
10.1	40.0	1.2	8.2
14.2	85.0	1.3	11.4
18.1	99.0	1.5	12.7
21.4	8.5	1.6	4.3
24.9	50.0	1.8	10.7
28.7	91.0	2.2	14.0

The SWR readings in this table are calculated values. It is not possible for VSWR bridges to give accurate readings above about 40:1 (this is the limit at 10% accuracy).
Most bridges are calibrated to 5:1 or less. For SWR calculations other than that indicated on your SWR bridge, see either the ARRL Handbook or the ARRL Antenna Handbook.

SWR may also be calculated from:

r = sqrt (REF/FOR)

SWR = (1+r)/(1-r)

WHERE:

FOR is forward power

REF is reflection coefficient (reflected power)

Matched loss is the loss that will occur when the load at the end of the transmission line is perfectly matched to the line. In other words, a 50 Ohm resistive load at the end of a 50 Ohm coaxial cable will indicate an SWR of 1.0 : 1.0. The loss will be the loss published by the cable manufacturer.

Let's use an example of an antenna fed with 100 ft of RG-58A coax cable. The data used for this example was taken from the ARRL Handbook (2000), pages 19.5-19.6.

Assume the antenna is a perfect match for our coax cable. I used Eznec to model an antenna for 80 meters above perfect ground, and 14 meters high.

The SWR indicated was 1.00125. From the loss table on page 19.5 of the Handbook, at 3.5 MHz our cable loss is approximately 0.75dB (15.9 watts). If our transmitter power is 100 watts, then 84.1 watts reached the antenna and is radiated.

Now lets use 24.9 Mhz (12 meter band). The SWR (from the software) is 8.34. Again, from page 19.5 of the handbook, our cable loss is approximately 1.2 dB (a loss of 24.1 watts). Referring to Handbook page 19.6, the additional loss due to SWR is approximately 1.8 dB (33.9 watts). Our total system loss? 58 watts!

If we used 300 Ohm line, our SWR at 3.5 Mhz is 9.0, and at 24.9 Mhz it is 4.34. The transmission line loss at 3.5 Mhz is approximately 0.17 dB (3.84 watts). The additional loss due to SWR is 0.7 dB (17.9 watts). The total loss at 3.5 Mhz for the 300 Ohm line is 18.74 watts or 81.26 watts to the antenna. The transmission line loss at 24.9 Mhz is 0.5 dB (10.9 watts). The additional loss due to SWR is 0.45 dB (9.84 watts). The total system loss at 24.9 Mhz is 20.74 watts.

This is just one example of the effects of SWR on performance. There are many more cases where an extreme SWR with coaxial line severely limits the power going to the antenna to be radiated, For further examples, consult the informative cahart on page 19.7 of the ARRL handbook. To recap:

Frequency	Loss w/ 50 Ohm coax	Loss w/ 300 Ohm coax
3.5 MHz	15.9 watts	58 watts
24.9MHz	18.7 watts	20.7 watts

ANTENNA TUNERS

Are antenna tuners necessary? If all your antennas are capable of a SWR match to less than 2: 1 for the frequencies you want to use then the answer is no. But this is seldom the case.

Antenna tuners is a misnomer. They do not tune the antenna. They do provide a matching network to make the input to the transmission line that goes to the antenna look like a good match to the output of your transmitter.

There are manual tuners and automatic tuners (ATU).
The inductor in the circuit may be a taped coil or a rotary inductor. In the past few years ATUs have had tremendous improvement. Speed has improved, firmware and memory has improved and there are many reasons to consider an ATU for your station.

I hear stations tuning up, it is usually a weak signal and only lasts less than a second. Typically the ATU reduces the power output to two Watts, then selects components that have been used before for this frequency. Compared to the time it takes to adjust a manual tuner this is a great improvement. ATU memory has improved. If you are at or near a frequency that has been used before instead of tuning, the previous settings are put in place in a fraction of a second. Remote location of an ATU is becoming more prevalent. This means that there is less loss of power in the coax cable due to mismatched loss.

There are however, some reasons to use a manual tuner. The manual tuner does not consume any DC power. The relays in the ATU do draw some current. The sum of current drawn by all the energized relays can amount to an Amp or more. If the ATU uses latching relays then the current draw may be near zero once the relays have been selected.
If you are involved in low power emergency operations where the only source of power is batteries the manual tuner may be the better choice for you. Make a chart of your settings and band changes can be made in a few seconds.

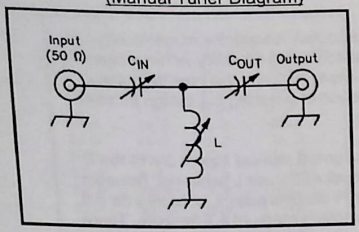
If you are a contest operator and constantly changing bands and frequency within a band you will be ready to go on the new frequency within a second of pressing the button to make the change.

Most of the current manual tuners are of the T type. Almost all ATUs use L networks, however a few use a Pi configuration. L networks do not have the matching range of a T network. There are many areas of the Smith Chart they cannot reach with a series L and shunt C no matter how many relays or components are in use.

All antenna tuners cause a loss of RF power. This loss is negligible compared to the loss of power caused by not creating a match to the output impedance of the transmitter.

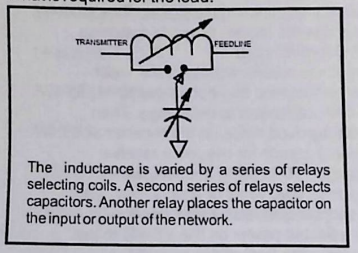
MANUAL TUNERS
Almost all of the manual tuners use a T network which provides the largest possible matching range. (5-01t match.jpg)
There are three adjustments to make, input capacator, inductance and output capacitor. To start put both capacitors to mid-range. Then listen to background noise on the receiver and adjust the inductance for maximun receive signal strength. Then using the minimum transmit power, (two watts or less is ideal, your unit may vary), adjust each capacitor for minimum reflected power on the VSWR meter. Once you have the best match record the frequency and antenna tuner settings. You will need to do this for each band. On a band like 80 meters you may need to do this for many parts of the band. *See next page for illustration.*

(Manual Tuner Diagram)



AUTOMATIC TUNING UNIT

These use an L network. The variable inductor is a bank of inductors with relays to put the sum of inductors in series for what is required for the load. The variable capacitor is a bank of capacitors with relays to put the sum of capacitors in parallel for what is required for the load.

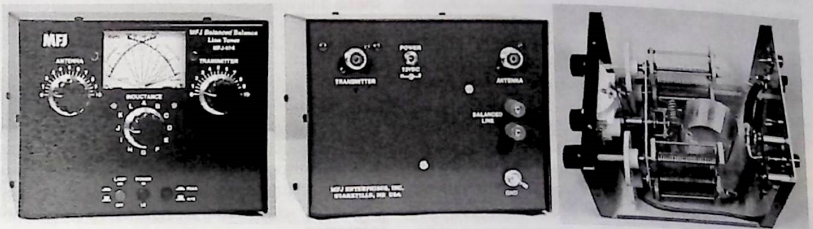


The inductance is varied by a series of relays selecting coils. A second series of relays selects capacitors. Another relay places the capacitor on the input or output of the network.

One more relay is used to put the capacitor on the input side of the L network for higher impedances or to switch it to the output side of the network to match lower impedance loads.

Many of the current ATUs also have large amounts of memory to save the frequency and relay settings for quick band or frequency change. There are even some that have a frequency counter and algorithm to calculate what is needed for present conditions and then set all relays for this first guess. Then just a few more relay switches for the final selection.

MFJ-974HB ANTENNA TUNER



The MFJ974HB has a balanced output network. It is rated at 300 Watts. There is a 1:1 current balun on the input of the tuner.

I have used this tuner from 160 m to 6 m to feed my loop antenna and make contacts. Minimum reflected power on the tuner meter matches perfectly with the 1:1 SWR meter in my transceiver.

A chart of frequently used frequencies vs MFJ-974HB settings was prepared and rubber cemented it to the front of the tuner. It takes only a few seconds to be tuned up on another band.

The impedance of an antenna does change a small amount from wet to dry weather conditions. When using the loop antenna, (described in chapter 4) I find this true on 80 m more so than the other bands. So expect that minimum reflected power settings to change a very small amount. However one day on 40 m I found a large change. Later I realized that the inductor switch was set to E instead of F. The mistake was made because I did not look at the switch from directly in front of the switch. Only on 160 meters do I need to make any changes to the output connections. This is due to the antenna that I am using. If I had more length in my loop antenna this would not be necessary.

The front panel of the MFJ-974HB does have a switch to go to unbalanced tuning, however I have to connect the leads of the ladder line together to feed it against ground. I have a separate DPDT knife switch to do this.

If you want an efficient balanced output tuner and your power is 300 Watts or less the MFJ-974HB would be a good choice.

MFJ-949E ANTENNA TUNER

The MFJ-949E is designed to match your transceiver to almost any antenna configuration. I have used it on dipoles, verticals, long wire V antennas, traveling wave antennas and other, all with good results. The antenna selector switch makes it very convenient to switch quickly from one antenna to another. At one time I had two verticals and a dipole few with 450 Ohm line. The dipole required the use of the tuner's circuits and built in balun. The verticals did not require the use of the tuning circuits. It was most educational to switch quickly to any one of these three antennas and notice which antenna gave me the best receive signal. I also used the selector switch to find our which antenna was best on transmit by using the same technique while in contact with another station. Never operate this switch while transmitting, but you can change the switch position when the key is up or during a pause in speaking when using SSB.

The tuner has a built in 50 Ohm dummy load capable of handling 300 Watts of power. A dual meter movement is used to display forward and reflected power simultaneously. The SWR is read by the needle that swivels in the left land corner of the meter. Transmitter power output is read by needle that swivels in the right hand corner.

There is a switch to change from average power to peak power, making it easier to determine readings while transmitting with single sideband

MFJ-986 ANTENNA TUNER

Most manual antenna tuners use a T network using two capacitors and a tapped or roller coil in the tuning network. This means that there are three adjustments to make while trying to find a match that will give the lowest SWR. This also means that there may be more than one set of adjustments that will give you a good match. Of these different setting there only one that will give you the best match and present the lowest loss at the same time. Trying to keep up with three interacting adjustments can be time consuming and frustrating. The MFJ-986, while still a T match type of tuner, has only two tuning controls.

The procedure is similar to the MFJ-949E except a continuously variable roller inductor replaces thefixed inductor. Repeat these adjustments until no further improvement can be made. Log the frequency and tuning adjustments for future reference.

The tuning circuit uses a differential capacitor tuning with 2 stators and 1 rotor and a roller inductor.

There is a selector switch that will select either of two coax feed antennas and a balun, that can be used to feed a balanced feedline, plus a bypass position that may be another antenna or an external dummy load.

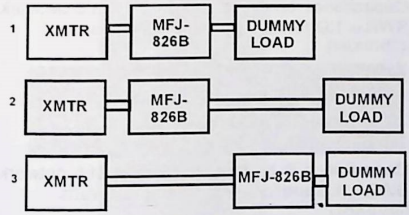
SWR metering is done with a cross meter movement that reads forwared and reflected power in two ranges, 200 or 2000 Watts. There is also an average/peak swith to aid in measuring ouput power while operating using SSB.

MFJ-826B DIGITAL SWR/WATTMETER

The MFJ-828B is a high accuracy digital SWR / Wattmeter and frequency counter. It covers 1.8 to 54 MHz. It can auto range or be set to full scale of 25, 250 or 1500 Watts. It also measures frequency, forward, reflected power and SWR. You may select average or peak power with a hold time of 1, 2 or 3 seconds.To measure frequency requires a steady carrier.

Although the purpose of this unit is to monitor the output of your transmitter and the SWR on the feedline, which it does very well, it can also be used for testing of feedlines. The fact that power is displayed to a tenth of a Watt and SWR to a hundredth makes this great for testing coax cables and connectors.

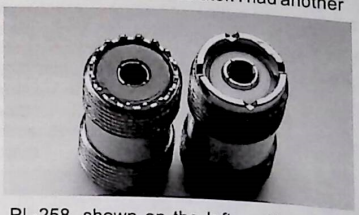
I have two pieces of RG-58 coax with PL-259 connectors, one is 18 feet the other is 24 feet. Using these and a good dummy load I did some tests.



Test set up 1 was done with short pieces of cable.

	XMTR				
FREQ	PWR	826B	LEN	REF	SWR
TEST 1					
3.60	20.0	23.9	1	0.0	1.00
14.10	20.0	24.1	1	0.0	1.00
50.10	20.0	19.8	1	1.3	1.68

TEST 2 Was done with 18', 24' cables with PI-259 connectors on them. The 42' length was obtained by joining the 18' and 24' cables with a PL-258 connector. I noticed a jump in SWR when I joined the two lengths together. The right PL-258 had a phenolic or bakelite insulator. I had another



PL-258, shown on the left, with teflon as the insulator. It is worth the small increase in cost of coax connectors to get the teflon insulator. Another test I did was to swap the ends of the 18' and 24' and redo each test. If there is a difference in VSWR it shows that there is a problem with the cable or connectors.

Connecting two cables together will give you an impedance lump. This is especially true using UHF connectors. Just be aware of this and make measurements so you can understand the losses. These losses are not significant until you get to VHF frequencies.

	XMTR					
FREQ	PWR	826B	LEN	REF	SWR	
TEST 2						
3.60	20.0	20.0	18	1.0	1.57	L
3.60	20.0	19.7	18	1.0	1.58	NL
14.10	20.0	20.0	24	1.2	1.65	L
14.10	20.0	19.8	24	1.2	1.65	NL
50.10	20.0	19.8	42	1.2	1.65	
50.10	20.0	19.9	42	1.2	1.65	

The L or NL shows which end of the cable is connected to the Wattmeter. *L=Labeled end; NL=Non Labeled end*

Test 3 shows the matched line loss. As the line lengthens the SWR goes down and as the frequency goes up the losses increase at the square of the frequency increase. Compare the power measured in test 1 to test 3. This shows matched line loss.

FREQ	XMTR PWR	826B	LEN
3.60	20.0	18.0	18
3.60	20.0	22.6	24
3.60	20.0	21.9	42
14.1	20.0	23.0	18
14.1	20.0	22.6	24
14.1	20.0	21.0	42
50.1	20.0	17.0	18
50.1	20.0	16.6	24
50.1	20.0	14.4	42

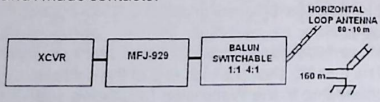
When I make a cable I label one end of the cable with a label showing the length of the cable. If swapping the ends of a cable shows a different SWR then the cable is damaged or a connector is at fault.

MFJ-929 INTELLITUNER AUTOMATIC ANTENNA TUNER

This tuner will automatically tune any coax fed or random wire antenna 1.8-30 MHz at full 200 Watts SSB/CW. It can match 6-1600 Ohms (SWR up to 32:1).

You get a digital SWR/Wattmeter with backlit LCD, antenna switch for 2 antennas, built-in radio interface and built-in internal BiasTee for remote tuner operation.

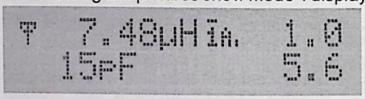
This is truly a very fast tuner. I tested it on all bands from 160 meters to 10 meters. It found a match and I made contacts.



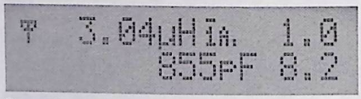
Although I used a 1:1 / 4:1 switchable balun, it was used in the 1:1 position on all bands with this ATU. An 18 inch piece of coax cable went from the output of the tuner to a balun to feed the ladder line.

Since the loop antenna was made with 85 meters of wire it could not expected to provide a reasonable impedance to the tuner on 160 meters. On this band the ends of the ladder line were connected together and fed against ground.

The following two pictures show mode 4 display.



Capacitance on antenna side of the L network, SWR is 1.0, forward power is 5.6 Watts.
(3549 KHz)



Capacitance is on transmitter side of L network. SWR is 1.0 and forward power is 8.2 Watts.
(3975 KHz)

I liked this display since it showed the value of the components in the L network and where the capacitance is located. Other selectable displays are: frequency, SWR and bar graph displays of forward and reflected power .

Once the tuner had been used on all bands the switch from one band to another seemed to be instant.

BALUNS

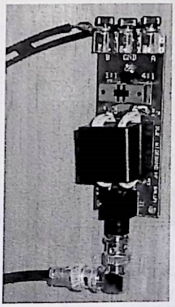
A balun is a transformer the converts electrical signals from unbalanced, such as the output from your transceiver, to balanced, such as feeding parallel wire lines. The balun could also be used at the end of a coax cable to feed a balanced antenna.

The balun can also be used to change impedance, such as feeding an antenna that might have an impedance other than the impedance of the coax cable that goes to the antenna. They use electromagnetic coupling for their operation.

If you feed a balanced antenna with an unbalanced feedline you should not expect to get the pattern that the antenna could provide if fed with balanced feed.

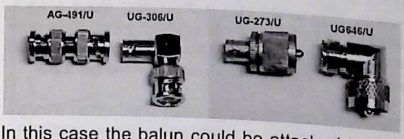
The output of our transceivers is 50 Ohms unbalanced. That means that one of the output conductors is connected to ground.

ELECRAFT BL2 BALUN



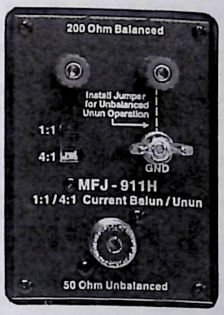
This balun comes as a kit from Elecraft. It took about 30 minutes to build. It is rated at 250 Watts and the bandwidth is 500 KHz to 55 MHz.

I have used the Elecraft BL-2 balun very successfully to feed the 85 meter loop antenna. This balun has a switch to select 1:1 ratio or 4:1 ratio. I have found this very useful in getting a match on some bands so that the final amplifier impedance is matched. I have been using a 12 inch piece of coax to connect from the transceiver to the balun. The coax connector is a BNC female You could use a BNC male to male adaptor and a BNC male to female right angle adaptor to mount the balun directly to the transceiver instead of using the piece of coax cable.



In this case the balun could be attached to the transceiver directly. But then the switch might not be conveniently available.

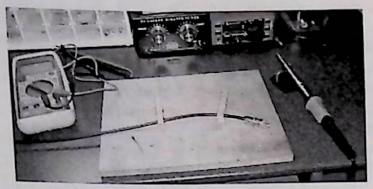
MFJ-911H BALUN



This MFJ unit has a switch to select from 1:1 or 4:1 ratios and also a connector to make it an unbalanced to balanced transformer at either impedance ratio.

It is rated at 300 Watts and the bandwidth is 1.8 to 30 MHz.

SOLDERING BOARD



On a piece of half inch plywood that is 12 inches by 9 inches I fastened two spring clothes pins using screws, this allows the clothes pins to swivel. This gives you a third and even a forth hand while handling a hot soldering iron. This gets used any time I am soldering cables or small parts. It also prevents damage to the desk top.

The digital multimeter will not prove that a coax cable is good but it will quickly prove continuity and find shorts.

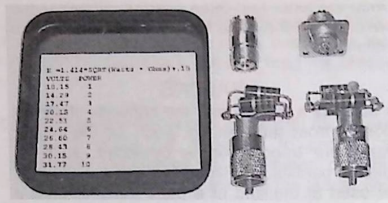
DUMMY LOADS

I cannot stress strongly enough how important dummy loads can be. It is a piece of test equipment that will prove to you whether your other test instruments are accurate or not. All of the test equipment in this chapter can benefit from the use of a dummy load in one way or another.

I have four dummy loads. Two are built with PL-259 coax connectors. These are made of three 150 Ohm two Watt resistors in parallel. One of these has a diode and capacitor to measure peak voltage.

E=[1.414*SQRT(WATTS*OHMS)]+.15

The .15 allows for the voltage drop across the diode.



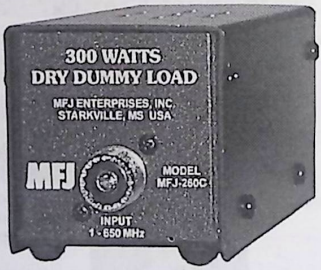
In a small box I have the dummy loads that I use most often. Rubber cemented to the inside lid of the box is the formula and list of voltage vrs power output.

.

The useful limit of this design is 10 Watts. Limits are the peak inverse voltage of the 1N34A which is 35 volts. The other limit is the power rating of the resistors. 10 Watts into six Watts of resistors is good only for a few seconds, before damaging the resistors.

Other dummy loads that I have are a surplus 200 Watt load good to 2300 MHz and the MFJ-260 C dummy load.

MFJ-260C DUMMY LOAD

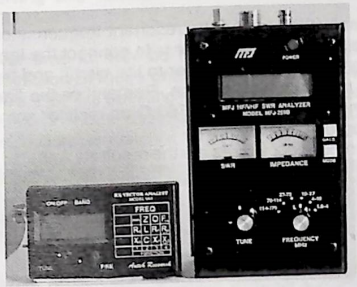


This unit is packages in a 2 ½" x 2 ½" x 7" perforated box with a so-239 connector on one end. The other end has contains a derating curve.

The maximum power that this load can handle is 300 Watts for 30 seconds. It will handle 100 Watts for 90 seconds and 25 Watts continuously. The load is rated for use between 1 and 650 MHz. The Bird Watt meter does not show any reflected power from this dummy load at any frequency I have used it for within the frequency range of 1 to 150 MHz.

MFJ also makes a 1000 Watt rated dummy load, the MFJ-262.

ANTENNA ANALYZERS



I have the good fortune too have both the Autek model VA1 and the MFJ-259B. One is pocket size, take it up the tower with you. The other has analog meters making it easier to tune to a null or peak. Each has advantages over the other in many different ways.

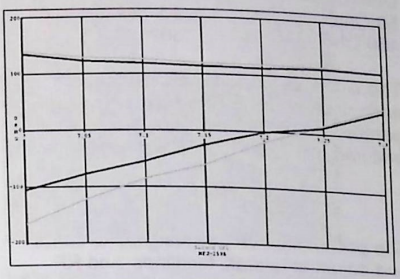
The upper limit for measurement of Z is 1000 Ohms for the Autek VA1. The upper limit for measurement of Z is 650 Ohms for the MFJ-259B.

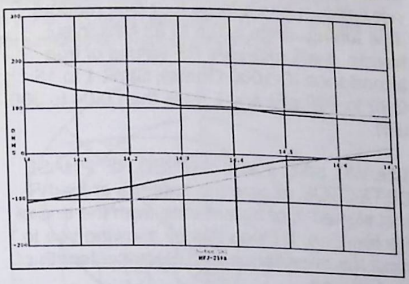
$$Z = \sqrt{R^2 + X^2}$$

I was interested in looking at the measurment of the loop antenna using each analyzer.

I took R and X readings across the 40 meter band with each analyzer, they did not look the same. These readings were taken several day apart. Do expect change from dry to wet weather.

I then took the reading within a few minutes of each other. Here are the results.





The readings from the two units show slightly different numbers at the higher values, the crossing of the zero Ohm line is in very close agreement. Either unit would give you the information to help you get your antenna tuned.

Results of testing these units with precision resistors and my dummy load.

7 MHz	Autek	MFJ
Dummy load	53	51
50 Ohms	51	49
150 Ohms	148	155
14 MHz		
Dummy load	52	52
50 Ohms	50	47
150 Ohms	136	136

The Autek comes with precision resistors, 2 each of 50 and 150 Ohms. By using series or parallel combinations you can check the accuracy at 25,50 75, 150 and 300 Ohms.

AUTKEK VA1

The pocket size VA1 is designed to check and adjust antennas, feedlines, and RF networks. It has a large four digit readout. The tuning range is 0.5 to 32 Mhz in six bands. It will measure RF values of true impedance (0-1000 Ohms), SWR 1 to 15:1), C (0 to 999 uF) and L (less than 0.04 to 300 uH).

The VA1 adds a true SIGNED RF PHASE DETECTOR to give the antenna or load R and signed X of an antenna from the end of the feedline. It Does this by allowing you to input the impedance and electrical length of the feedline.
Uses a 9 Volt battery.

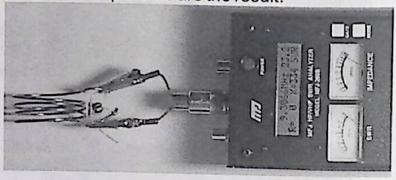
MFJ-259B

MFJ-259B gives you a complete pictures of your antennas performance. You can read antenna SWR and Complex Impedance 1.8 to 170MHz

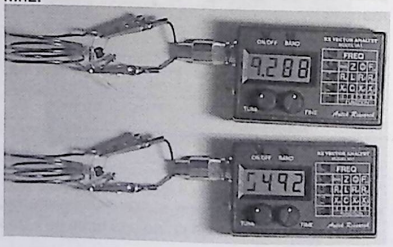
Read Complex Impedance as series resistance and reactance (R+jX) or as magnitude (Z) and phase (degrees). You can determine velocity factor, coax cable loss in dB, length of coax and distance to a short or open in feet. You can read SWR, return loss and reflection coefficient at any frequency simultaneously at a single glance. Also read inductance in UH and capacitance in pF at RF frequencies. Large easy-to-read two line LCD screen and side-by-side meters clearly display your information.
Uses 10 AA cells.

RESONANT FREQUENCY

An easy way to find the resonant frequency of a parallel coil and capacitor is to connect the leads from the antenna analyzer to the circuit and tune for maximum impedance. Remember the limits for measuring Z, I put a 560 Ohm resistor across the across the circuit.
The next two pictures are the result.



Adjust frequency for maximum Z on the impedance meter. The frequency reading is 9.306 Mhz.



The last picture is two pictures combined. The Autek was set to alternate between frequency and impedance. Frequency was adjusted for mazimun Z. The Autek reading was 498 Ohms, The frequency read 9.293 MHz.

The measured inductance for the coil was 1.02 uH and the capacitor was 287 pF.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Solving this formula shows the frequency is 9.302 Mhz.

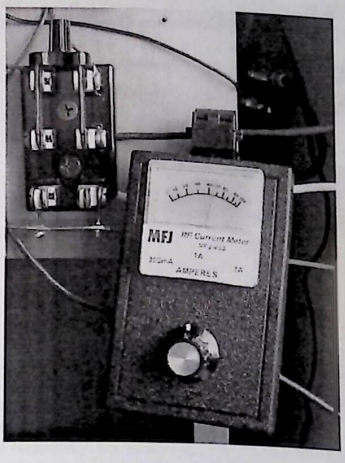
Over time in may be necessary to check the calibration of these units. MFJ has on their web site a PDF file outlining calibration procedures. Autek provides calibration information in their instruction manual.

Keep some precision resistors and capacitors available so that you can verify the accuracy of your antenna analyzer.

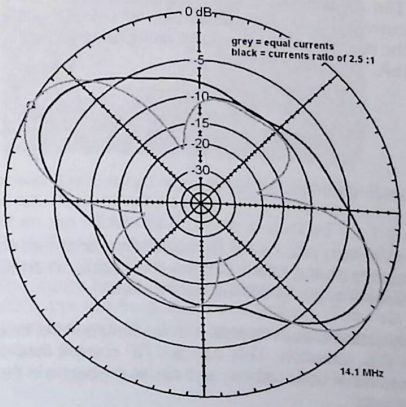
MFJ-853 RF CURRENT METER

The MFJ-853 is a calibrated clamp-on RF current meter that accurately measures RF current in antenna elements, ground wires, coax shield. Slips over mobile whip to tune for maximum current/radiation. A three position switch selects full sale current of 0.3, 1, or 3 Amps. Non-metallic case minimizes field disturbance for accurate reading. No power source needed, It is powered from the current flowing thru the sense coil.

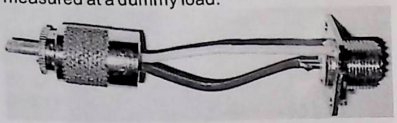
The next picture shows the shows the MFJ-853 hanging from one lead that goes to the 450 Ohm feedline. It shows 430 mA of current flowing in this lead. If you are feeding a balanced antenna compare the current in the other lead to see if it is the same.

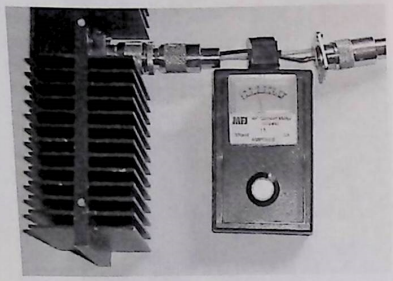


Below shows the radiation pattern distorted due to a 2.5:1 current unbalance. Current should be the same on both sides of the wire.



Below is an adaptor so that RF current may be measured at a dummy load.





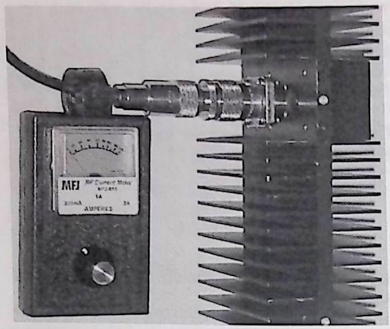
The RF current is measured only in the center conductor of the coax cable.
The power out of the transmitter was 45 Watts. The switch was in the 3 Amp position. The RF current meter showed 0.32. In this switch position the meter reading should be multiplied by 3 for 960 mA.

$$I = \sqrt{\frac{WATTS}{OHMS}}$$

Solving for I shows .94 mA.

In the next picture the RF current meter shows no current on the outside of the coax cable when 80 Watts was going into the dummy load.

An antenna does radiate, the feedline is in the field of this radiation. This can put RF current on the outside of coax cables, and cause problems in the station.



The sense coil will take up to ½ inch cable.

To unlatch the sense coil was a bit of a challenge at first. Study the diagram in the manual and have patience. I have opened it many times to do these tests. It gets easier but it does not open quickly.

This is a simple piece of test equipment that I find most useful to have. It does not require a battery.

MFJ also makes the MFJ-853H with scales of 3, 10 and 30 Amps.The MFJ-854 is a clamp on Ammeter that measures RF current from as little as 1 mA to 3 Amps in six ranges.

Having the ability to measure RF current provides you with a more complete picture of your station and it's performance.

FERRITE BEADS

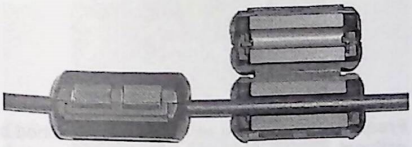
Ferrite beads are used to reduce RF current flowing on the outside of coax cables. Right is an open bead, ready to be put over a coax cable.

Electromagnetic Interference (EMI) is interference from computers, DSL equipment, motors, electric fences and anything that can create electric sparks.

Radio Frequency Interference (RFI) may come from any transmitter. Amateur, CB, broadcast, police, fire etc.. These are interference sources that you may have to deal with.

Hopefully our transceivers have been designed with bypass circuits so the RF we radiate does not get back into the transceiver via the mike, data line, key, or push to talk switch. If the mike bites you lip, the key stings your finger or your output is distorted then RF feedback could be the cause. Good grounding is the first step to prevent these problems.

Common mode current is current in phase on the conductors of a cable. An RF current meter may help you detect this. A second solution is applying Ferrite beads or RF chokes to the cables going into your transceiver. These come in many forms, the snap on are the easiest to apply.



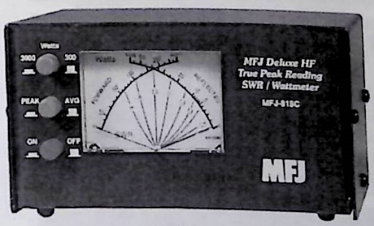
These are the MFJ-700A4. The left one is closed the right one is shown open. A small flat blade screwdriver will open then for removal. These are for RG-58, RG-59, RG-6U or any ¼ inch cable.

MFJ has these up to ¾ inch diameter.

MFJ-700P9 shows the range of sizes and methods of putting ferrite chokes on cables.

MFJ-815C SWR / WATTMETER

This cross-needle meter will monitor both forward and reflected power simultaneously. There are buttons to select either Peak or Average reading and power ranges of 300/3000 watts forward and 60/600 Watts reflected. Frequency coverage is 1.8 to 30 MHz with a measurement accuracy of ±10%. The average



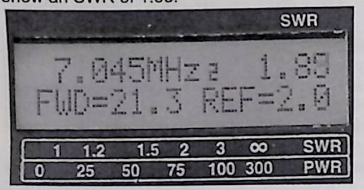
power is measured when the PEAK/AVG button is out. Peak envelope power (PEP) is measured when the PEAK/AVG button is pushed in. The Peak Reading function of this meter requires external 12 VDC or a 9 volt battery to operate. The meter lamps will function with external 12 VDC, but not from the 9 volt battery. The rear panel features SO-239 connectors for input and output.

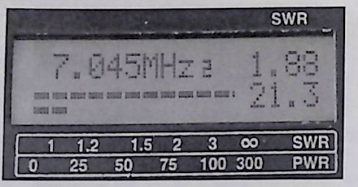
MFJ-828B DIGITAL SWR / WATTMETER

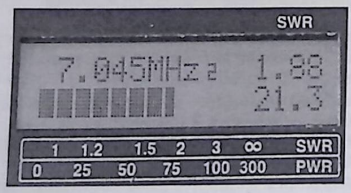
This unit was reviewed as test equipment earlier in this chapter. The accuracy of the MFJ-828B impressed me.

The power range is 25, 250 or 1500 Watts. The frequency range is 1.8 to 54 MHz.

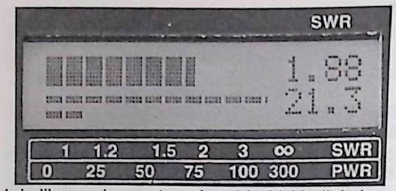
A press of the "menu" switch rotates the display through four displays. Upon the next power up the display last used will be present. For this test I set the output of the transceiver to 18 Watts. I tuned an antenna tuner and a dummy load to show an SWR of 1.88.







Average or peak power may be selected. The readout of frequency requires a steady carrier.



I do like analog meters, but this 60 bit digital display is great.

BIRD MODEL 43 WATTMETER

The Bird Model 43 Thruline Wattmeter has an accuracy of +/_ 5% of full scale. Frequency range is 450 Khz to 2.7 Ghz, Power range is 100 mW to 10 kW.

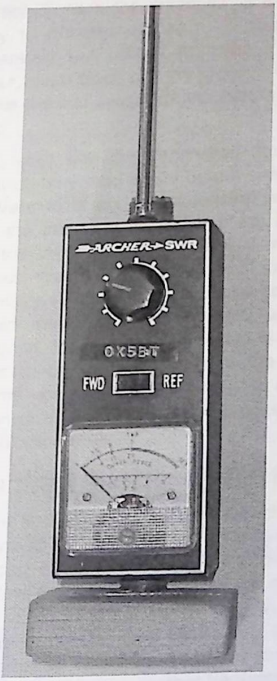
Frequency and power ranges are determined by optional plug-in elements. This meter may be ordered with UHF or N type connectors.

This Watt meter may be installed and left in a 50 Ohm coaxial line. Either coax connector may be connected to the transmitter and the other connecter to the load or antenna tuner. The circular elements plug in to the front panel and may be rotated for forward or reflected power readings.

Although an old design, the Thruline Watt meter is still available. What makes it so versatile is the wide range of frequency and power elements that you may select.

FIELD STRENGTH METERS

A field strength meter is, to me, an assurance that I am radiating a signal. This meter is and Archer SWR / field strength meter that I bought about 1965. I no longer use the SWR feature. I mounted it on a board and keep it on the operation desk. This is a piece of equipment that I took to Greenland when I was OX5BT.



MFJ-801 FIELD STRENGTH METER

This field strength meter is ideal for reading the relative field strength from your antenna or just to sit on your operating desk so that you know that the antenna is radiating. It does not require a battery.

TROUBLESHOOTING ANTENNAS

In any troubleshooting effort divide the areas of possible trouble into as many parts as possible. If you notice that the transmitter (transceiver) is not loading correctly you should be asking yourself, 'lis it the transmitter?" "Is it the antenna tuner?" "Is it the feedline?" "Is it the antenna?" It is relatively easy to troubleshoot each of these blocks separately but difficult to make a decision about which block has the problem when you notice the first symptom and before you start tests.

First, start with the transmitter. Mount a 50 Ohm dummy load at the output connector of the transmitter and check loading and VSWR with the metering circuits that are build into the transmitter. The 50 Ohm dummy load insures that the transmitter has the proper impedance attached to the output circuit. This should insure that it will work as it was designed. If you have a problem at this point it has to be the transmitter or the 50 Ohm dummy load has a problem. If all meter readings seem proper then proceed to the next block.

TROUBLESHOOTING FEED LINES

Before finding fault with an antenna, test the feedline to be sure that the problem is not in that part of the antenna system. The reason that "the feedline is new" does not mean that there cannot be a problem with it. It is possible that a feed line can show no problems at one frequency but can be the cause of troubles at another frequency.

The simplest test of a feedline is with an ohmmeter. You cannot prove that a feedline is good with an ohmmeter but you can find the most common problems, an open or a short. When using an ohmmeter be sure to zero the meter by shorting the test leads together and adjusting the zero adjustment until the meter needle is over the zero mark at the low end of the Ohms scale. If you have one of the new digital meters with automatic zeroing this step is not necessary.

A shorted feedline can certainly be a cause of high standing wave ratio. A simple ohmmeter check with the meter on a high Ohms scale (R X 1000 or 10,000) is a good check. Do not connect the feedline to the antenna. Some antennas have a matching network at the feedpoint that keeps the antenna at DC ground, this type of network would show a short circuit to an ohmmeter. Connect the ohmmeter leads between the center pin and shield of the feedline connector at one end of the coax. It does not matter which lead from the ohmmeter goes to the center pin of the coax line under test. The meter reading should be on the high end of the scale, (open circuit) several thousand Ohms or more: a reading less than full scale may indicate that the coax has water in it or is shorted. If this is old coaxial cable it may be best to replace it. If the coaxial cable passes this test it may still have a problem. We have proven that the cable is not shorted but we have not proven that the cable is not open. Connect a short jumper or a shorted female coaxial fitting (SO239) to the other end of the coaxial cable and repeat the ohmmeter test, but now use the lowest Ohms scale (R X 1). Re-zero the meter and take a reading, it should be close to zero Ohms. If it is not, then either the cable has an open center conductor or braid. Check the coax fittings first. If they are of the soldered type re-heat all the solder joints and add some new solder. If this fails you could

cut off the connectors and check the cable without connectors. If the cable is good then re-install the connectors and test again.

While these tests will find faults with coaxial cable they will not PROVE that the cable is good. If you are using the wrong impedance cable the above tests will pass with flying colors but will still give you a poor SWR when connected to a good antenna. The best test of all for coaxial cable is to put a good 50 Ohm dummy load on the far end of the cable, instead of the antenna, and use a SWR / Wattmeter or antenna analyzer to test the cable on several bands.

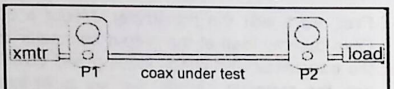
TROUBLESHOOTING WITH AN SWR / WATTMETER

You will need a source of RF power at the frequency to be used. Your transmitter or transceiver will provide the necessary signal. Connect a short (2 feet or less) coaxial cable between your transmitter (transceiver) and the SWR bridge. Connect the cable to be tested to the SWR meter. Connect a 50 Ohm dummy load to the far end of the coaxial cable that is being tested. Use the minimum power that will deflect the meter in the SWR meter. Read the manual for use of your SWR meter. Some SWR meters require that you set the forward power to full scale on the meter and then move a switch to read SWR on the reflected meter scale. Other meters will require that you read forward power and then reflected power and calculate SWR with the formula.

$$r = \sqrt{ref/for}$$

$SWR = (1 + r)/(1 - r)$
where ref is the reflected power
for is the forward power

Dual meter SWR bridges will read forward power on one meter needle and reflected power on the other meter needle.If the coax is 50 Ohm cable and the dummy load is 50 Ohms you should have a perfect SWR. Any reading larger than 1.3 should make you suspicious of the coax cable. You may want to decide not to keep this cable in the circuit. Coax cable over a period of time will degrade and cause higher losses than when it was new. To test for line losses compare the power at each end of the feedline while the feedline is terminated in a 50 Ohm dummy load. If the loss is noticeably greater than 1 dB above the new cable value then you should consider replacing it.



Put the Wattmeter at the output of the transmitter and measure power. Then move the Wattmeter to the other end of the feedline and again measure the power. Matched line loss is determined as shown below in the LOSS formula.

LOSS dB = 10 log P1/P2 * line length (ft)/ 100

P1 is the power at the output of the transmitter.

P2 is the power at the end of the feed line.

Again a dummy load in used to help you troubleshoot.

If you have 100 feet fo RG-58 cable and the measured loss at 28 MHz is 3.6 dB or greater then it is time to replace that cable.

Example: You are testing a 50 foot length of RG-58 cable. At 28 MHz you measure 10 Watts of power at the input of the cable and 7 watts at the dummy load. The loss per 100 ft for cable Would be:

```
dB = (10 log (10/7) * (100/50)
LOSS(per 100 ft) = 3.1 dB
```

RG-58 is expected to have 2.6 dB of loss per 100 ft of cable at 28 MHz. I would elect to continue to use this cable, but would make yearly checks since it has begun to degrade.

Cable losses of various coax cables per 100 feet, loss in dB.

CABLE	3.7 MHz	28 MHz
RG-174	2.5	6.5
RG-58	0.7	2.6
RG-8	0.4	1.4
RG-8(FOAM)	0.3	0.9
9913	0.2	0.7

MEASURING MATCHED LINE LOSS WITH THE MFJ-259B

Matched line loss is the loss in a cable when the load at the end of the cable is a perfect match. 50 Ohms, no reactance on a 50 Ohm cable.

It is so easy to get a direct reading. Connect the cable being tested to to the MFJ-259B. Leave the other end of the cable open. Adjust the band switch and frequency knot to the frequency you want to measure the cable loss.

Press the MODE switch once. "Coax Loss" is displayed. Read the display. I measured a 42 foot piece of RG-58 and the display gave me these measurments.

```
29 MHz 1.4 dB.
3.6 MHz 0.7 dB.
```

MEASURING MATCHED LINE LOSS WITH THE AUTEK VA1

Matched line loss may be measured ONLY where the cable is a quarter wavelength of an odd multiple of quarter wavelengths.

Connect the cable to the VA1, leave the other end of the cable open. Set the display to show impedance and adjust frequency for a minimum value. Using the same 42 foot length of cable the meter showed these readings. The twelve page instructions that came with the VA1 instructs you to multiply the minimum impedance readings by 0.17.

```
27.33 MHz  Z= 8 * 0.17 = 1.36 dB.
3.727 MHz  Z= 3 * 0.17 = 0.51 dB.
```

LOSSES DUE TO SWR

Losses in coaxial cable go up rapidly when the cable is operated at a high SWR The graph in chapter three, page 8 shows how total line loss compares with matched line loss and SWR as measured at the transmitter end of the coax. Matched line loss is the loss that will occur when the line is perfectly matched at the antenna end of the coax. Refer to the chart showing cable losses above. The next three examples are all using the same data.

You are using 64 feet of RG-8U coaxial cable. The CABLE LOSSES chart shows that this cable has 1.4 dB of loss per 100 feet at 28 MHz.

Matched line loss is = 1.4 * 64/100 = 0.9 dB.

Graph, chapter three page 8. Find the vertical line that is labeled 5. Follow this line up to the point it cross the 0.9 curve. (curve plotted with diamond shaped marks) Follow across horizontal to the left side of the graph and read just over 3 dB of total line loss. Half of your transmitter power is wasted due to line losses. There is nothing that you can do about the 0.9 dB loss, that is built into the cable. To reduce this loss use a better grade of cable or use a shorter cable. The 2.1 dB loss portion of this loss can be removed by making a better match between the cable and the antenna.

Next look at the graph in chapter three, page 7. Again enter the graph at the vertical line labeled 5. Follow the line up to the curve plotted with diamond shaped marks. Head horizontally across to the left side to discover that the real SWR is about 10:1. The proper place to read SWR is at the antenna terminals. This however is seldom done and I monitor SWR at the transmitter end. I do however make some measurements at the antenna, so that I know that the match at least started out being close to 1:1.

An alternate way to measure line loss is by measuring SWR at the input to the line when the line is either open or shorted. I prefer using an open line for this test. The loss along the line will make the SWR appear much better than it really is. You can find the matched line loss using the graph in chapter three, page 7. If you measured the SWR as 10:1 then enter the graph on the bottom scale at 10. Follow the vertical line to the curve and then follow horizontally to the left and read the matched line loss at 0.9 dB. This is one test where the higher the SWR the Better.

Caution! Many transmitters do not work into a high SWR very well. Use as low an output power as possible when making this type of test. Five Watts or less from a 100 Watt output amplifier should enable you to make this type of measurment.

TROUBLESHOOTING A DIPOLE

A dipole or inverted V is one of the simplest and most used. ham antennas. A dipole in free space will have a feed point impedance of 73 Ohms and, no reactance. As this antenna comes closer to ground the feed point impedance will change and the frequency of resonance will change. At the practical heights that most dipoles are mounted, the feed point impedance will be lower than 73 Ohms and resonance will have shifted lower in frequency because of capacitive coupling to ground. An antenna analyzer is the better instrument to use to check for resonance and impedance.

The object of these tests is to find the resonant frequency and shorten the dipole so that resonance will be moved up to your favorite frequency. If a 40 meter dipole is cut for the center of the band you should usually be able to work the whole band with SWR of less than 2:1.

TROUBLESHOOTING ROTATING TRAPPED DIPOLES AND YAGIS

If you fail to get a good SWR on one band there are three possible problems. One is that a trap is bad or mistuned. Another is that nearby metal or other antennas have detuned the antenna. The third is that a length of tubing section has changed possibly due to loose clamps. First verify that all element lengths are correct and if you have a Yagi make sure that element spacing is correct. If the reflector and director spacings are swapped it will have a serious effect on the impedance of the antenna. Rotate the antenna and check SWR at different azimuth headings. Any variation in SWR is an indication that nearby guy wires, other antennas or other metallic objects are having an effect on the tuning of the antenna.

A trap is a high Q parallel resonant circuit. If the next lower frequency band does not work then the coil in that trap may be open circuited. Do not try to take a trap apart since this will void the warranty. The balance between inductance and

capacitance is critical and requires special equipment to assure proper adjustment. Refer to the trap trouble-shooting section for checking individual traps.

SWR CHANGES WITH THE WEATHER

Ice or heavy snow that sticks to the elements and traps will cause the resonant frequency to shift lower since the radiator appears to be fatter. If your antenna is close to the ground the effect of more conductive soil during wet weather will shift the resonant frequency lower due to capacitive loading. Any cracked or torn plastic caps will allow moisture to enter the traps. Moisture in a trap can affect the resonant frequency of the trap. Putting any type of sealant on the hot end of traps will likely detune them and create voltage breakdown problems since the outer end of a trap is a high voltage point (some traps are designed so that the inner end is the hot end). If the plastic caps on the ends of traps are split then obtain new caps and replace them.

SWR CHANGES WHEN POWER CHANGES

If SWR varies with power level on one or more bands the problem may be in the SWR bridge (or harmonic output content of your transmitter).

There can be a non-linear variation of diode action at different power settings. This is common with inexpensive bridges. It is possible to overload a diode in the forward power mode. The diode is now on a different slope of the curve in relation to the reflected power diode which is not overloaded. The end result is your SWR will apparently increase when you go from low to high power. Example: 1.1:1 at 50 watts, 1.4:1 at 800 watts. Observe SWR as you slowly increase power. If SWR slowly increases you may be overloading the bridge. If you see a large jump in SWR at a specific power level not related to a slow increase in power, you have voltage breakdown troubles with your antenna system.

Possible causes: Poor or intermittent connection in coax or connection in a trap. High voltage breakdown in a trap can sometimes be detected by sniffing the end cap to determine if it has burned.

SWR too high on one or more bands

Mistake in assembly or a defective trap. See trap troubleshooting. On concentric capacitor type traps look for a trap in backwards. Cushcraft traps have the threads of a self tapping screw visible on the inside tubing on one end of the trap. This is the end that should be closer to the boom.

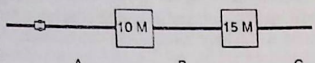
TROUBLESHOOTING A MULTI-BAND TRAPPED DIPOLE

The multiband trapped dipole is tested in the same manner as the dipole except that there are different sections of the antenna that must be adjusted for different bands. The traps in the dipole will act as high impedance points at different frequencies. The traps closest to the center of the dipole are for the highest frequency band, usually 10 meters.

Always troubleshoot a trapped antenna starting at the highest frequency and when that band is working well, move down in frequency to the next lower band. The traps are adjusted to be resonant at different frequencies and may be tested with a dip oscillator or antenna analyzer. .

If you suspect that the traps may be a part of the antenna's problem refer to TESTING TRAPS. The length of wire to adjust on a trapped antenna is always the length next to the trap for that band. and is closest to the center of the antenna. The lowest frequency in. a trapped antenna is adjusted by varying the length of the wire between the end insulator and the trap closest to the end of the wire. Shorten the wire to move resonance higher in frequency and lengthen the wire to move the resonant frequency lower.

TRAPED DIPOLE ADJUSTMENT



One half of the dipole is shown. A is the dimention from center insulator to 10 Meter trap, adjusting this dimention will tune the 10 meter band. The length of B will tune the 15 meter band. Adjustment of C will tune the lowest frequency band. The lowest frequency band may be 14 MHz or 7 MHz or 3.5 MHz., Any band lower in frequency than 21 MHz may be chosen, this is your choice. The dimentions on both sides of the center insulator should be the same.

In the diagram adjust length A for the highest frequency and length B for the next higher band and length C for the lowest frequency band.

TROUBLESHOOTING A MULTIBAND TRAPPED VERTICAL

There are two types of trapped vertical antennas. One is the electrical half wavelength. This type does not need a radial system but may require a counterpoise so that the antenna has something to load against. The other type of trapped vertical antenna is an electrical quarter wavelength.

This type of antenna must have a radial system. I am assuming in the following examples that the traps in the antennas from highest frequency trap at the bottom, and go up in order up to the lowest frequency trap at the top of the antenna. There are some antennas in which this is not the case. Check the information that applies to your antenna to understand the exact order of the traps in your antenna.

TROUBLESHOOTING THE ABOVE GROUND TRAPPED VERTICAL QUARTER WAVELENGTH ANTENNA

Troubleshooting the above ground trapped vertical is very similar to troubleshooting a ground mounted vertical.

First, verify the radials installed are per the manufacturer's instructions, and are not broken. Next, verify good conductivity to the location where they are attached, and that no corrosion exists.

If all this is satisfactory, then refer to the previous section, while always being on the lookout for visual signs of failure, as described previously in the sections on trapped antennas. This can indeed be a lengthy process, but be sure to explore all areas.

This type of antenna must have a radial system. I am assuming in the following examples that the traps in the antennas go from highest frequency at the bottom, and go in order up to the lowest frequency toward the top of the antenna. There are some antennas in which this is not the case. Check the information that applies to your antenna to understand the exact order of the traps in your antenna.

TROUBLESHOOTING THE ABOVE GROUND TRAPPED VERTICAL QUARTER WAVELENGTH ANTENNA

With this type of antenna check the radials, the lengths of tubing between traps and the traps. Make sure that the radials start at the base of the antenna and have a good electrical connection to the base. The radials need to be the suggested length. Usually this length is given by the formula:

LENGTH (ft.) = 234.0/FREQUENCY (MHz)

Without radials this antenna will not work. Start troubleshooting this antenna at the highest frequency band. If the resonate frequency of the antenna went up, then check the length suggested in the manufacturers literature. (The tubing may have slipped down.) Check the radials for this band. Do they have a good electrical connection to the base? Is the length of radials correct? See TROUBLESHOOTING TRAPS if this seems to be a trap problem. Now check the next lower frequency. Repeat the radial and tubing length checks. For the lowest frequency band the adjustment is to the length of tubing above the lowest trap. Also check the radial connections and lengths.

TROUBLESHOOTING THE GROUND MOUNTED MULTI-BAND TRAPPED VERTICAL QUARTER WAVELENGTH ANTENNA

At ground level this antenna has the advantage of using ground as part of the antenna radial system. Radials for the ground mounted antenna do not have to be one quarter wavelength long and may be considerably shorter, if ground conductivity is high. Radials may be laid on the ground or the ground may be split open with a lawn edger and the wire pushed in an inch or so. You may use any size wire so long as it does not break easily. Either bare or insulated wire may be used. As long as there is a good electrical connection to the radial system there is seldom any problems in this part of the antenna. If it seems necessary to check the radial system the easiest way to do this is to lay an additional wire on the ground that is one quarter wavelength long

(Length ft. = 234/Frequency MHz)

for the band that needs checking. If the addition of this one radial has no significant improvement in VSWR then the original radial system may be considered good. Make the aluminum tubing length checks suggested in the "TROUBLESHOOTING ABOVE GROUND TRAPPED QUARTER WAVELENGTH ANTENNAS" section. Start with the highest frequency band and work up the antenna to the lowest frequency band.

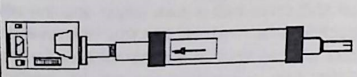
TROUBLESHOOTING TRAPS

Traps are parallel resonant circuits whose purpose is to act as an insulator at the frequency to which the trap is tuned. Normally traps are tuned to the center of the band but

there are exceptions. I urge you to get information about the tuning of the traps in your antenna from the manufacturer. Ask for both the dip meter frequency and the operating frequency of each trap.

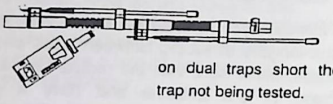
Many trap problems are mechanical faults that are easily corrected. If the trap labels have faded or fallen off then mark the traps before removal so that they may be put back in the proper place. Mark the ends of the traps so they do not end up in backwards. On those traps with the large diameter outer cover it is important that there not be any movement between the outer cover and the inner aluminum tube. Check each trap to insure that the cover is tightly secured. The cover is large diameter tubing between the two large black end caps. Any movement of this cover will cause frequency shifts in the trap and an intermittent high VSWR condition on the antenna. You may easily test for a loose cover while the antenna is still assembled. Grasp the cover in one hand and the trap tubing in the other hand, apply a moderate amount of pressure first in a clockwise and then a counterclockwise direction about the axis of the element. If the cover slips even a small amount it will require tightening. Remove the black cap from the end of the trap on the side towards the boom of the antenna. A hex head screw will then be visible underneath. Tighten the screw with an appropriate screw driver or nut driver. Be careful not to apply so much force as to strip out the sheet metal screw. If the hole is already stripped, or gets stripped accidently, it is an easy matter to fix by substituting a #10' 3/8" or 1/2" self tapping screw in the enlarged hole.

Capacitive couple to a trap with a covered coil



To adjust frequency remove the plastic caps, remove a self tapping screw, slide the outer tube along the inner tube until the trap is set to frequency. Drill a small hole so that the self tapping screw can be installed.

Inductive couple to an open style trap that has the capacitor to the side of the coil



on dual traps short the trap not being tested.

Adjust frequency by sliding aluminum rod in or out of small diameter aluminum tubing. It will be necessary to heat the shrink tubing with a heat gun or hair dryer. When the shrink tubing cools the adheasive will again hold the aluminum rod.

To do a frequency test place the trap on an insulated surface (such as large cardboard box) and couple a dip oscillator to it. On traps that have a covered coil coupling to the dip meter can be done by inserting the dip meter coil into the tubing on one end of the trap. This is capacitive coupling. The capacitor is formed between the outer tubing and the inner tubing, it is adjusted by sliding the outer tubing with respect to the inner tubing. A dip should be easily found, pull the dip meter coil out of the trap tubing slightly and re-dip the

meter, continue this until you have the minimal discernible dip. At this point use a receiver to determine at what frequency the dip meter is oscillating. Compare this frequency with the dip meter frequency provided by the manufacturer.

Some traps have exposed coils with the capacitor mounted to one side. On these traps coupling to the trap may be inductive. Bring the dip oscillator coil close to the trap coil and find the dip and then move the dip oscillator away from the trap slightly and again tune the dip meter to find the best dip. Continue this procedure until the minimal discernible dip is found. Minimal coupling will provide the most accurate results. This type of trap is adjusted in frequency by moving the aluminum rod in or out of the small diameter aluminum tubing. It will be necessary to use a heat gun or hair dryer to soften the adhesive in the shrink tubing before the rod will move. As soon as the adhesive cools it will again grip and hold the aluminum rod.

It should be noted that the dip meter frequency is lower than the operational frequency of the trap. This is caused because the trap will load the dip oscillator and lower its frequency. You should use the manufacturers listed oscillator frequencies as a guide. Temperature and humidity can have a +/- 100 KHz effect on traps. If the frequency readings are within 100 to 200 KHz of the listed amounts the effect upon the assembled antenna will be minimal. Shorted turns or other serious defects will cause wide shifts from the norm. One or two megahertz is a definite indication of a defective trap. If you find such a trap, do not attempt to repair it yourself if the trap is still in warranty. All coils are sealed and are difficult to repair properly. A trap that measures high in frequency by 500 KHz to 1 MHz probably has a shorted turn in the coil. Install the traps and recheck the antenna. VSWR checks on an HF beam that is near ground will usually show that the resonant frequency is much lower that when the beam is up at normal height. A Yagi may be tested near ground by mounting it vertical, with the reflector several feet above ground. In this position ground will have minimal effect.

TESTING ANTENNA TRAPS USING A NOISE BRIDGE

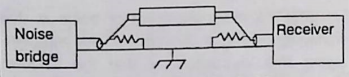
Usually the resonate point of traps is determined by using a Dip Meter. The problem of using this instrument is that the frequency displayed on the dial, or read out on a frequency counter is lower than the real resonate point of the trap. This is caused by the loading of the tuned circuit in the Dip Meter by the tuned circuit of the trap under test. On the higher frequencies at 14, 21 and 28 MHz the problem is not severe, however at 40 meters the apparent error may become much greater (percentage wise).

A list of traps frequencies taken from a popular antenna manufacturer and their operational frequencies and dip frequencies follows:

Band MHz	Operational Frequency	Dip Meter Frequency
28	28.80	27.87
21	21.25	20.17
14	14.20	12.92
7	7.15	5.81

I think I would have found the dips for the top three bands but I probably would have given up trying to find that dip at 5.81 MHz.

There is another way to test traps that was suggested to me by W1JR. It requires a wide band noise source, the Noise Bridge can be that source of noise. The settings of the dials on the noise bridge are not used except to set them for maximum noise in the receiver. Refer to the diagram for the test setup. The resistors should be fairly small, I used 18 Ohm resistors but any value in that range should work. Tune the receiver until you get minimum noise. On my test setup I was able



The resistors are 18 Ohms. I built this test set up into a length of coax cable. Connectors are on each end of the cable to attacth to receiver and noise bridge. Clip leads are used to attatch to each end of the trap.

to find the resonant frequency of a trap and when re-testing the trap I would come to within 10 to 20 KHz of the first reading. The Results of the noise bridge test closely followed the results of checking these same traps on a network analyzer.

The principal of this setup is that the resistors swamp the output of the noise bridge and the receiver input. The trap is a parallel tuned circuit in series with the receiver input and at resonance the trap will provide the maximum amount of attenuation of the noise signal.

INFORMATION NEEDED TO TROUBLESHOOT ANTENNA PROBLEMS

If you are not making progress solving your antenna problems then seek help from other hams or the manufacturer of your antenna. They cannot give you much help unless you can give them a good set of symptoms and a complete set of VSWR curves for the bands that the antenna covers. Use the following chart for suggested VSWR readings:

BAND	MEASURE EVERY	USEFUL BANDWIDTH
1.8 MHz	10 KHz	25- 30 KHz
3.5 MHz	25 KHz	60-100 KHz
7.0 MHz	50 KHz	100-200 KHz
10.1 MHz*	25 KHz	50 KHz
14.0 MHz	50 KHz	300-350 KHz
18.1 MHz*	25 KHz	100 KHz
21.0 MHz	50 KHz	350-450 KHz
24.9 MHz*	25 KHz	100 KHz
28.0 MHz	200 KHz	600-900 KHz

* Entire band covered because the band is narrow.

When making VSWR readings use as little power as you can. If your transmitter has an automatic tuner built in be sure to bypass it. If you have been using an antenna tuner bypass it. You want readings that reflect what the antenna is doing not what some other tuning circuit is causing. If your problems are on all bands it would be a good idea to disconnect the antenna from the feedline and connect a dummy load to the feedline. Check the VSWR at the ends and center of each band, it should be nearly perfect at all frequencies, if not then fix the feedline before resuming VSWR readings with the antenna connected to the feedline.

Enough readings are required so that a curve

can be made or visualized. This curve will determine where resonance should occur. If resonance is not near the expected frequency this would suggest looking at reasons that might cause this condition.

Some common errors are to expect greater bandwidth on the 80 and 40 meter bands. Most manufacturers design their antennas to tune to any part of the band, but the useful bandwidth will be much less the entire band. A ten meter beam, either mono band or tri-band should not be expected to work over the entire 1.7 MHz of that band with good performance. Expect to cover a bandwidth of less than 3% of the frequency for which the antenna is designed. As the frequency applied to a Yagi goes up in frequency the parasitic element lengths are not changing and at some frequency, usually about 5% above the design frequency, the director will start to become long enough to act as a reflector. This will cause the pattern and impedance of the antenna to change radically.

SYMPTOMS OF A POOR GROUND

Some of the symptoms of a poor ground are distorted audio in your transmitted signal, problems with electronic keyers, RF bites when you touch the case of the transceiver while transmitting and other unexplained symptoms that disappear when you feed the transceiver into a dummy load. If your ground lead has any appreciable length you are likely to have a grounding problem. A good ground one quarter wavelength away from your equipment will look like an open circuit. You might try running a second ground lead in parallel with the first one. Make the second lead twice as long at the first. In that way if one length does not provide ground the second one by virtue of being a different length may give you a better ground. If lack of a good ground continues to be a problem you should consider an artificial ground circuit.

An artificial ground circuit is a series resonant circuit, in series with your ground lead, that will electrically adjust the length of your ground lead for a low impedance at your radio equipment. MFJ makes an Artificial RF Ground unit that is adjustable over a large range and has a built in meter to help you determine when it is adjusted correctly. This unit can be used to enhance a real ground connection that is poor as well as make use an artificial ground consisting of a random length of wire.

There can be many different causes of problems within an antenna system. You need to understand what each piece of test equipment can do for you. Choose the correct test instrument and understand the data that it can give you. If you have a set of VSWR readings draw some of the curves so that you can visualize the response of your antenna at different frequencies. Then you can decide how to make length adjustments. When troubleshooting a trapped antenna be suspicious of only the traps on the bands that show poor VSWR readings. Usually only one trap goes bad at a time, you do not have to troubleshoot all of them. Separate feed line problems from antenna problems. May all of your antenna problems be small ones.

FREQUENTLY ASKED QUESTIONS

- I am using coax to feed my antenna. Do I need to use a balun?

Yes, if the element being fed is split at the center.

No, if the element being fed is a solid element being fed with a gamma match.

- Should I use a balun plus a choke on my beam?

No, use only one or the other.

- Can I use my tri-bander on 12 or 17 meters?

You might use an antenna tuner to provide a proper impedance to the transceiver and therefore get some useful radiation from the antenna. However do not expect that this antenna will be efficient or have a useful pattern on frequencies that it was not designed for.

- Should I use a certain length of feed line to my antenna?

Normally the length of feed line for a matched system is not important. If you are trying to measure VSWR and do not have the VSWR bridge at the antenna terminals then a length of feed line that is equal to an exact multiple of a half wavelength will repeat the antenna impedance at the other end of the line.

- How can I protect my antenna from weather?

Once an antenna is tuned and you are satisfied with its performance you may coat the antenna, terminals and hardware with a coat of marine varnish. Latex base RTV will provide a good weatherproof seal that is a good electrical insulator. Scotch Kote is another good waterproofing product..

- My transmitter is supposed to put out 100 watts. On most bands it does put out 100 watts but on one band I only get 90 watts out, where did the other 10 watts go?

The missing 10 watts never came out of the transmitter. If the load on that one band is not quite correct there will be slightly less power out. The loss of power for this example is:

$dB = 10 \log 90/100 = -0.45$ dB

This is such a small loss of power that is should be ignored.

- In which direction does my beam have the strongest signal?

The beam will send and receive best in the direction that the director is from the driven element. The director is the shortest element in the beam.

- After I connected my feed line to the antenna I checked it with an ohmmeter and it was shorted, what should I do?

The input to many antennas is by a transformer. A transformer will show a short to an ohmmeter but not be a short at radio frequencies. Check the information that came with your antenna or check with the manufacturer if you are in doubt about the input circuit of your antenna.

- Will I damage my antenna if I use an antenna tuner between the transmitter and the feed line?

No. Use an antenna tuner only on the bands that do not present a good VSWR. On bands with a good VSWR you may use the tuner but why bother, on those bands bypass the tuning circuits.

UNITS OF MEASURMENT

Where did the names come from that we use in describing units of measurement used in antennas and feed lines? They are the names of prominent scientists, mostly from the 18th century, whom we honor by using their names as units of measure.

Ampere, Andei-Marie (1775-1827) French. He was a physicist, mathematician, chemist and philosopher. Ampere reasoned that the deflection of a compass needle caused by and electric current could be used to construct a device to measure the strength of the current, an idea that eventually led to the development of the galvanometer. He also realized the difference between the rate of passage of electric current and the driving force behind it. In 1827 he published the mathematical formulations of electromagnetism, Ampere's Law is an equation that relates the magnetic force produced by two parallel current carrying conductors to the product of their currents and the distance between the conductors. We use his name for the unit of current.

Bell, Alexander Graham (1847-1922) British born American who lived much of his life in Canada. The decibel is about the smallest change in acoustic power that the ear can detect. It is one tenth of a Bel, named after Alexander Graham Bell who discovered the logarithmic amplitude response of the ear.

Faraday, Michael (1791-1867) British. He made pioneering contributions to electricity, inventing the electric motor, electric generator and the transformer. He also discovered electromagnetic induction and the laws of electrolysis. Faraday was the first to observe that the plane of polarization of light is rotated in a magnetic field. His name is used as the unit of measurement of capacitance.

Henry, Joseph (1797-1878) American physicist who carried out experiments in electromagnetic induction. He discovered self induction. The unit of inductance was named the henry in 1893.

Hertz, Heinrich Rudolf (1857-1894) German. In 1888 he realized that Maxwell's equations implied that an electric wave could be produced and would travel through air. Hertz went on to confirm his predictions by constructing an open circuit powered by an induction coil, and an open loop of wire as a receiving circuit. As a spark was produced by the induction coil, one occurred in the open receiving loop. He went on to determine the velocity of these waves, which we know as radio waves, is the same as that of light. Hertz devised experiments to show that the waves could be reflected, refracted and diffracted. His name is used as the unit of frequency, one cycle in one second is equal to one Hertz.

Ohm, Georg Simon (1789-1854) German. This physicist is remembered for Ohm,s law. In 1825 he began the work that led to his law of electricity. He investigated the amount of electromagnetic force produced by a wire carrying a current, expecting it to decrease with the length of the wire. He used a voltaic pile to produce a current and connected varying lengths of wire to it, measuring the electromagnetic force with the magnetic needle of a galvanometer. Ohm found that a longer wire produced a greater loss in electromagnetic force. We use his name for the unit of resistance.

Volta, Alessandao (1745-1827) Italian. Physicist who discovered how to produce electric current and built the first electric battery. Volta also invented the electrophorus as a ready

means of producing charges of static electricity. We use his name for the unit of measurement of electro-motive force (Volts).

Watt, James (1736-1819) Scottish. Watt is known for his improvements on the steam engine. He also studied the conversion of energy to mechanical power. We use his name for the unit of electrical power.

The symbol for Ohm is the upper case Greek letter omega, Ω . All of the others listed here use the upper case first letter of their last name as an abbreviation of the unit of measure.

History buffs may wish to visit their library and learn more about these and other pioneer scientists.

GLOSSARY

ANTENNA - An electrical conductor or array of conductors that will radiate or collect radio frequency energy.

ANTENNA TUNER - A network of variable reactances used to resonate and impedance match an antenna system at the operating frequency to the radio equipment.

BALANCED LINE - A symmetrical two wire line. Both conductors are above ground, at any instant of time a point on one line will be positive while the equilivent point on the other line will be the same value negative.

BALUN - A device used to feed a balanced load with an unbalanced line or vice versa. It may be a choke or transformer and may provide a 1:1 or 4:1 (or some other ratio) impedance transformation.

BASE LOADING - A system used to resonate an electrically short antenna to a lower frequency. A coil is inserted in series with the antenna at the base to cancel capacitive reactance.

BRIDGE - A circuit used in the measurement of impedance, resistance or standing wave ratio. When the bridge is adjusted for a balanced condition the value of the unknown being measured may be read on a calibrated dial or meter.

BROADSIDE ARRAY - Dipole elements arranged in one plane and fed in phase. Maximum radiation is at right angels to the plane containing the elements.

CENTER FED - A system of feed where the feed line is connected at the electrical center of the antenna element.

CENTER LOADING - Insertion of inductance in series with the antenna element at or near the center of an element. It is used to lower the resonant frequency of an electrically short element.

COAXIAL CABLE - A transmission line in which one conductor is inside and shielded by the other. The center conductor is held in place with either insulators or solid insulation. Solid insulation is known as dielectric.

COLLINEAR ARRAY - An array of dipoles that are mounted end to end in a straight line. Maximum radiation is at right angles to the line of the elements.

CORONA DISCHARGE - An arcing type of discharge directly into the air. This may occur at a high voltage point on an antenna, when high power is used.

COUNTERPOISE -A wire or group of wires close to ground but insulated from ground. It is a conductor against which another conductor may be fed.

CURRENT LOOP - The point of maximum current along an antenna conductor.

CURRENT NODE - The point of minimum current along an antenna conductor.

DECIBEL - A logarithmic ratio of current, voltage or power. It may be used to compare one antenna with another or feed line loss by comparing power into the line with power output at the other end of the line.

DIELECTRIC - An insulator, usually referring to the insulation used in transmission lines.

DIPOLE - An antenna that is an electrical half wavelength and split at the center so that a feedline may be attached.

DIRECTIVITY - The property of an antenna element or elements that concentrates more radiated energy in one direction that in other directions.

DIRECTOR - A conductor, less than an electrical half wavelength, placed near a driven element and used to cause the antenna radiation to favor that direction.

DRIVEN ELEMENT - The element in an array that is connected to the feedline.

DUMMY LOAD - A resistive unit used in place of an antenna for test purposes. A dummy load will not radiate RF but will dissipate RF energy as heat.

DX-DISTANCE - DX when using HF is usually overseas or more than a 1000 miles. DX when using VHF or UHF means several hundred miles.

E PLANE - The plane of radiation that contains the electric field of an antenna. The E plane also determines the polarization of the antenna. The E plane contains the horizontal pattern of a horizontal antenna. (See H PLANE to further understand E PLANE.)

ELEMENT(S) - The conductive parts of an antenna or antenna array.

END FED - A system of feed for an antenna where the feedline is attached to the end of the antenna.

FEED LINE - A conductor or conductors used to move RF energy from transmitter to antenna or antenna to receiver.

FIELD STRENGTH - The intensity of radiation at a distance from the antenna.

FRONT TO BACK - A ratio relating to the radiation from the front and back of an antenna array.

GAIN - The change of radiated signal strength as compared to a standard antenna (usually a dipole).

GROUND PLANE - A series of conductors used to serve as ground for an elevated antenna.

H PLANE - The plane that contains the magnetic field of an antenna. The H plane is at right angles to the E plane. The H plane contains the horizontal pattern for a vertically polarized antenna.

HARMONIC ANTENNA - An antenna that will operate at harmonic frequencies of the design frequency.

IMAGE ANTENNA - The imaginary counterpart of an antenna visualized as being below ground.

IMPEDANCE - The combination of resistive and reactive components at the terminals of an antenna or feed line.

LINE LOSS - The power lost in a transmission line, usually expressed in dB.

LOAD - The device to which power is delivered. The antenna is the load at the end of a feed line. The feed line plus antenna is the load for the transmitter.

LOBE - A specific part of a radiation pattern where more energy is concentrated. Major lobe, minor lobe.

LONG WIRE - A wire antenna that is one or more wavelengths long.

MARCONI ANTENNA - A vertical antenna, usually an electrical quarter wavelength, fed against ground and shunt fed.

MATCHING - The process of changing impedance from one electrical circuit to another electrical circuit with a different impedance. When properly matched, the maximum amount of power will be transferred.

NULL - A condition where a minimum occurs. In a radiation pattern the weakest signal radiated is at a null. In a feed line the point where minimum current or voltage occurs. In a bridge circuit the point where balance occurs.

OPEN-WIRE LINE - A feed line that uses insulators periodically, the major insulator in the line is air.

PHASING LINES - Sections of feed line a specific length so that the signals in different parts of the array will have the desired phase.

POLARIZATION - The sense of a radiated wave. The wave may be polarized vertical, horizontal, circular or elliptical. Circular and elliptical waves may be either right hand or left hand circularly polarized.

RADIATION PATTERN - The graphic representation of radiated energy from an antenna.

RADIATION RESISTANCE - The effective resistance of an antenna ignoring losses in the antenna.

RADIATOR - An element in an antenna or array that radiates radio frequency energy.

RANDOM WIRE - A length of wire that fits the physical space available, it is seldom resonate. It must be fed with a matching network and is usually fed against ground.

REFLECTOR - A parasitic element, electrically longer than a half wavelength, used to enhance radiation in the opposite direction from the driven element. Ground may at times act as a reflector for some antenna installations.

RESONATOR - A loading coil used to lower the resonant frequency of a physically short antenna.

RF - Radio frequencies. Electrical energy that can be radiated.

SHUNT FED - A method of feeding a vertical antenna that must be grounded due to its design. A tower with antennas mounted at the top may be shunt fed on the lower frequency ham bands.

STACKING - A method of mounting two or more antennas to increase gain. The antennas may be either above or beside each other.

STANDING WAVE - The result of energy reflected from the end of an antenna or a mismatched feed line. Standing waves on antennas are desirable. Standing waves on feed lines are normally not desirable.

STUB - A section of transmission line used to cancel reactance or aid in impedance matching

SWR - Standing Wave Ratio. See VSWR.

T MATCH - A method of matching a feed line to an unbroken (a dipole is a broken antenna element) antenna element.

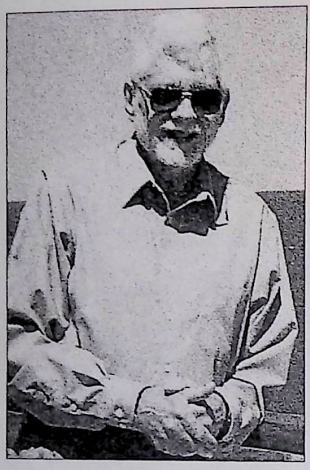
TRANSMATCH - An antenna tuner.

TRANSMISSION LINE - Feed line.

TRAP - A parallel circuit of inductance and capacitance used to create a very high impedance at a certain frequency in an antenna element. Traps may be used to obtain multi-band operation with one antenna.

VELOCITY FACTOR - The ratio of velocity of a radio frequency signal in a feed line as compared to free space. The dielectric material in the feed line causes the signal to go slower.

TROUBLESHOOTING ANTENNAS AND FEEDLINES



Ralph "Ty" Tyrrell, aka W1TF, was first licensed in 1946. Over the years, he held the calls W9NCF, W5INJ, and OX5BT, and W1TFS. Ralph held the Extra Class Amateur Radio License. He also held a Commercial FCC First Class Radio Telephone License (now known as General Radio License) with radar endorsement. He was passionate about CW, and took every opportunity to demonstrate why every good amateur should know Morse Code.

While in the U.S. Army, Ralph worked in an R&D unit attached to Fort Bliss and White Sands Proving Ground. He later joined Ford Aerospace, and was assigned to various satellite tracking stations in the U.S. and abroad. After 27 years, he retired from Ford, and went to work for Cushcraft, a major antenna manufacturer. After serving as technical support for five years, talking to literally thousands of amateurs about antenna problems, he felt a book dedicated to the *troubleshooting of antennas and feed lines* was needed. That book was originally published in 1992.

Ralph had a true passion for all things "ham." While canoeing across Canada, he carried his equipment with him. At the end of the day's canoeing, he could be found climbing trees to secure antenna wires and make contact with the outside world from the depths of the wilderness. Later, while traveling the U.S. for a decade in his motor home with his wife, Kathryn (N1INC), he kept antennas, masts and cable in the bottom of the vehicle, and successfully made contact from every state they stopped in.

A lifetime ARRL member, Ralph remained an active amateur throughout his life. After moving to Statham, Georgia at the age of 77, he helped found the Barrow County Amateur Radio Society (formerly BARES), as well as becoming a faithful participant in the activities of Ambassadors for Christ. He began work on this updated edition to reflect changes in technology that had come about since 1992. On August 6, 2009, a month shy of his 79th birthday, Ralph's key fell silent, as he succumbed to leukemia while still working on this book. Ralph was on the air for six decades. In addition to his wife Kathryn, Ralph spread the love of Amateur radio to his daughter Robin (KB1CZY) and his step daughter Tamar (N1INA).

This updated edition would not have been possible without a team of people who ensured that Ralph's final work would see completion: Duane Reynolds, WB2YAD, who provided invaluable real-world technical review and revision, Ralph's wife Kathryn for proofreading, and his son-in-law Scott Piehler who oversaw the revisions. While "Ty" may no longer be on the air, his influence will be felt on the airwaves for generations to come

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